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PRODUCTION OF CUTTHROAT TROUT (SALMO CLARKI) IN RELATION TO RIPARIAN VEGETATION IN BEAR CREEK, WASHINGTON

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Production of Cutthroat Trout (*Salmo clarki*)
in Relation to Riparian
Vegetation in Bear Creek, Washington

by

DOUGLAS JOHN MARTIN

A dissertation submitted in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

University of Washington

1985

Approved by Ernest O Salo
(Chairperson of Supervisory Committee)

Program Authorized
to Offer Degree Fisheries

Date 7 June 1985

Signature Douglas J Martin

Date June 6, 1985

University of Washington

Abstract

PRODUCTION OF CUTTHROAT TROUT (*Salmo clarki*) IN RELATION TO RIPARIAN VEGETATION IN BEAR CREEK, WASHINGTON

By Douglas John Martin

Chairperson of the Supervisory Committee: Professor Ernest O. Salo,
School of Fisheries

Removal of riparian vegetation can alter salmonid production in streams. In some cases, removal of riparian vegetation has enhanced fish populations by stimulating aquatic food supply. In other cases, however, physical disruptions of stream habitats resulting from removal of vegetation have decreased fish production. This study examined relationships linking fish production with riparian vegetation, excluding those associated with physical disturbance of habitat.

Bear Creek, a third-order stream on the Olympic Peninsula, was investigated before and after removal of riparian vegetation. Water temperature, aquatic insect production, and terrestrial insect fallout increased following streamside timber removal in a 1 km treatment zone. Temperatures averaged 2°C greater in the lower 500 meters of the treatment zone, but the upper 500 meters of the treatment zone did not change. Average annual biomass of aquatic insects in the upper 500 meters of the treatment zone was two times greater (6.1 gm^{-2} compared to 3.0 gm^{-2}) than biomass in the control zone. Biomass of aquatic insects increased in the lower treatment zone, as well. Insect fallout biomass (May-August) in the lower and upper treatment zones increased from 51 percent and 70 percent of the biomass in the control zone prior to treatment, to 64 percent and 102 percent of the biomass in the control zone following treatment.

More than 70 percent of the food biomass consumed by all age groups of cutthroat trout was composed of aquatic insects, despite the greater abundance of insect fallout. Only during the summer low flow period (August) when aquatic production was low, did insect fallout become more important than aquatic insects in the trout diet. Changes in prey utilization were associated with temporal differences in prey availability, and prey availability may have limited the level of food consumption.

Following canopy removal, mean weights of each age group of trout increased only in the lower treatment zone, but not always. Densities of age I and II trout increased only in the upper treatment zone. Differences in these responses to canopy removal were attributed to differences in food supply and temperature between the lower and upper treatment zones. Increased rates of food consumption were associated with increases in water temperature and food availability. This appeared to enhance physiological conditions for growth in the lower treatment zone. On the other hand, increases in trout density in the upper treatment zone were associated with increases in food availability without significant changes in water temperature. These results suggest temperature is a key factor determining how a trout population responds to canopy removal.

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INTRODUCTION

Results of studies concerning the effects of logging on juvenile salmonids demonstrate that riparian vegetation has a strong but varied influence on salmonid populations (Gibbons and Salo 1972). The removal of riparian vegetation has caused reductions of fish populations in response to changes in water temperature, increased sediment load, loss of cover, and changes in channel morphology (Hall and Lantz 1969, Burns 1972, Narver 1972, Moring and Lantz 1974, Cederholm et al. 1981, Scrivener and Andersen 1984). However, certain other reductions of riparian habitats have enhanced fish production due to favorable changes in photic and thermal regimes and increases in benthic invertebrate abundance (Aho 1976, Osborn 1980, Murphy and Hall 1981, Murphy et al. 1981, Hawkins et al. 1983). Contradictory results such as these may be explained by the specific effects canopy removal has on fish habitat and food resources. Recent studies suggest that clearcutting can potentially lead to enhancement of trout production if the stream channel is maintained physically (Triska et al. 1982). However, the effects of clearcutting on fish production separate from physical habitat alterations has not been previously examined. Therefore, the purpose of this dissertation is to investigate relationships linking fish production with riparian vegetation excluding those associated with physical disturbances.

RIPARIAN INFLUENCES ON SALMONIDS

Factors influencing the food supply, habitat, and production of fish living in a woodland stream are closely linked to the riparian vegetation complex (RVC). Shade from streamside vegetation is the primary factor controlling water temperature (Brown 1971), and also the limiting factor controlling primary production in coniferous forest streams (Gregory 1980). The removal of the forest canopy stimulated production of periphyton, resulting in an improved food base for the benthic macroinvertebrate community.

Comparisons among shaded versus unshaded stream sections have demonstrated greater densities and biomass of aquatic insects in association with greater biomass of periphyton in streams with open canopies (Erman et al. 1977, Murphy et al. 1981, Hawkins et al. 1983). Under closed canopy conditions, aquatic insect production and the structure of benthic communities were largely dependent upon inputs of fine particulate organic matter (FPOM) from riparian vegetation for food (Nelson and Scott 1962, Fisher and Likens 1972, Cummins et al. 1973, Hynes 1975, and Triska et al. 1982). Sedell and Triska (1977) found that inputs of large organic debris provided habitat sites and retention structures for FPOM and its processing.

The diet of juvenile salmonids in streams is composed of both aquatic and terrestrial invertebrate fauna. Although benthic invertebrates are the predominant food source, terrestrial food is known to account for at least 50 percent of the diet of salmonids during one or more months and nearly 100 percent of the daily food consumption during short periods of super abundance (Hunt 1975). The removal of streamside vegetation may have an effect on the abundance and taxonomic composition of insect fallout, which could have an effect on consumption by juvenile salmonids. Little is known about the factors that affect insect fallout, as this has not been studied in the Pacific Northwest.

While riparian habitats offer many stream populations a source of food, they also provide physical benefits. Large organic debris and the roots and stems of riparian vegetation are principal factors influencing the physical character of small and intermediate sized streams in the Pacific Northwest (Swanson and Lienkaemper 1978, Keller and Tally 1979, and Keller and Swanson 1979). The influence of regional geology on channel morphology is modified by the input of large organic debris. Large organic debris controls the routing of water, causing scour and deposition, creating riffles, pools, off-channel areas, and cover that provides spawning and rearing habitats for salmonids (reviews by Giger 1973, Hall and Baker 1975, and Reiser and Bjornn 1979). The roots and stems of live streamside vegetation improve bank stability, contributing to undercut bank formations that provide cover for salmonids (Meehan et al. 1977). During winter high-flow periods, log jams and undercut banks with tree roots and root wads dissipate the energy of flowing water and create pockets of velocity shelter that are utilized by juvenile salmonids (Hartman 1965, Bustard and Narver 1975, Tschaplinski and Hartman 1983, Murphy et al. 1984). Shade from riparian vegetation controls water temperature, which influences the behavior and distribution of juvenile salmonids in streams (Lantz 1971). Temperature is also a primary factor controlling the growth rate and governing the metabolic requirements of fish (Brett 1979).

Population size and growth are regulated through competition for food and habitat (i.e., density dependent factors), and by a variety of environmental factors (e.g., temperature, discharge, habitat quality) (Allen 1969, McFadden 1969). The growth of fish is partially dependent upon competition and the amount of food available. Reductions in the fish populations or increases in the amount of food available can reduce competition and correspondingly enhance growth rates (Fraser 1969, Mason 1976). Growth is also determined by the amount of food eaten and the amount of energy required to maintain metabolic functions (Brett 1979). These latter factors are controlled, for the most part, by water temperature. Since food supply and temperature are influenced by riparian vegetation, growth and production of fish may be greatly influenced by changes in the riparian community.

Territoriality, food supply, and the amount of suitable habitat also determine the abundance of juvenile salmonids in streams. Increases in food supply can result in an increase in fish density (McFadden 1969, Mason 1976). Juvenile salmon respond by altering the size of territories in response to changes in food abundance (Dill et al. 1981). Similarly, an increase in the amount of suitable habitat has resulted in an increase in population size (Hunt 1969). Since food supply and habitat are closely linked to the RVC, then population size and production also are influenced by riparian vegetation, as well.

In conclusion, recent studies suggest that riparian vegetation can have a strong influence on the production of juvenile salmonids through the control of factors that affect energy transfer (i.e., food availability and temperature) and/or through the control of factors that affect fish habitat (i.e., cover, channel morphology, and channel stability). Studies that distinguish between effects that energy pathways and habitat conditions play in controlling fish production are limited. Studies concerning the energy pathway have been concerned only with the effects of canopy removal on summer fish densities and summer production (i.e., Aho 1976, Murphy and Hall 1981, Murphy et al. 1981, Hawkins et al. 1983).

While results of these studies are only based on correlative analysis, studies concerning the importance of habitat conditions during winter and summer are based on both correlative analyses (e.g., Bisson and Nielsen 1983, Murphy et al. 1984, Tschaplinksi and Hartman 1983) and manipulative tests (e.g., Bustard and Narver 1975, Lestelle 1978, Elliott and Hubartt 1980, Dolloff 1983). Studies designed to test the effects of canopy removal on the energy pathway from changes in habitat conditions have not been conducted in the Pacific Northwest. Such information would provide a better understanding of the ecological relationship between riparian vegetation and fish production.

STUDY OBJECTIVES

The purpose of this study is to investigate relationships linking fish production with riparian vegetation, excluding those associated with physical disturbances. This investigation was conducted with three objectives:

1. to identify the relationships among food supply, food consumption, and production of cutthroat trout.
2. to determine the relative importance of aquatic and terrestrial invertebrates as food.
3. to determine the effect of canopy removal on aquatic and terrestrial food supply.

STUDY APPROACH

In order to expand our knowledge of the relationship between fish production and riparian vegetation, it is necessary to move beyond the post-impact correlative approach to a controlled experimental manipulation of the environment. In this study, riparian components that influence the energy pathway were isolated from the components that influence the habitat conditions, excluding temperature, by an experimental manipulation of the riparian zone. This was accomplished by removing all streamside timber that provided a forest canopy and selectively retaining understory vegetation and key streamside trees that provided structural integrity for the stream channel and banks. Felled timber was not removed during the study in order to eliminate physical disturbances of habitat which are normally associated with road construction and log yarding. The response of the fish population to this manipulation of the energy pathway was evaluated by conducting an intensive study, before and after treatment, of two adjacent stream sections designated as treatment and control zones. This study design provides a temporal and spatial reference which enables comparisons of population responses in treatment and control areas before and after treatment (Hall and Knight 1981).

DESCRIPTION OF STUDY AREA AND BACKGROUND INFORMATION

STUDY AREA

This study was conducted in the upper reaches of Bear Creek, a fourth-order tributary to the Bogachiel River, near Forks, Washington (Fig. 1). The study watershed has an area of 230 ha and is located in a remote part of the Olympic National Forest, which has no roads or logging activity. The study stream averages 6 to 10 m in width at bankfull flow and meanders (sinuosity = 1.2) through a relatively broad valley. It has an average gradient of 2.1 percent, and a discharge ranging from 0.02 m^3/s to 5.66 m^3/s.

Climate of the Bear Creek vicinity is oceanic with heavy winter precipitation (peak in December). Summers, however, are relatively dry. Precipitation averages 300 cm/yr and occurs mostly as rain at elevations below 600 m (Phillips 1965).

Bedrock of the area consists of Cretaceous sedimentary rock known as the Soleduck formation and is the oldest known rock in the Olympic Mountains. The rocks are profoundly folded and consist of coarse textured, thickly bedded graywacke, interbedded with fine textured, thinly bedded mudstone, siltstone, and argillite (Snyder et al. 1972). Stream banks which are occasionally weakened by tree windthrow, are heavily eroded during high flow periods.

The stream is bordered by an old-growth forest consisting of western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*), with frequent clumps of red alder (*Alnus rubra*). Woody vegetation along the stream includes: vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), Devil's club (*Oplopanax horridus*), salal (*Gaultheria shallon*), tall blue huckleberry (*Vaccinium ovalifolium*), and red huckleberry (*V. parvifolium*).

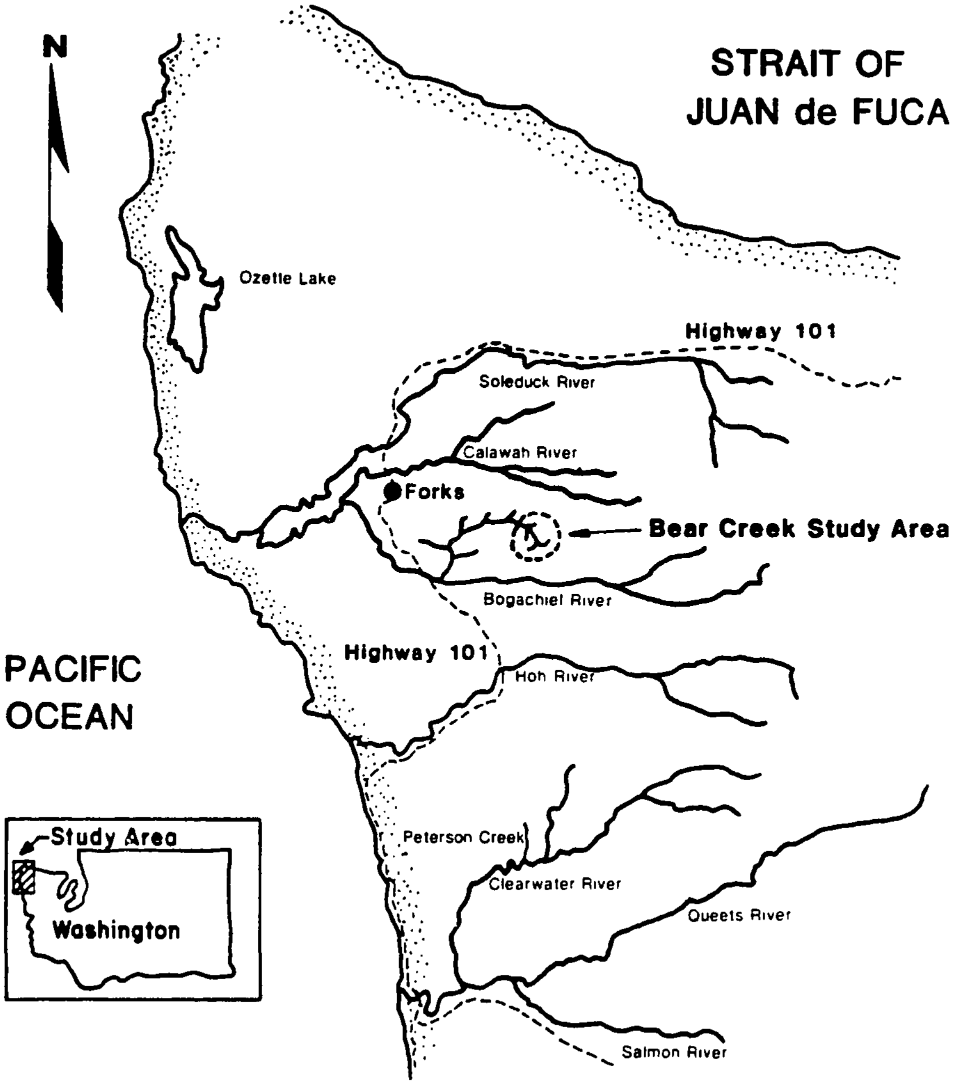

Figure 1. Western Olympic Peninsula with location of Bear Creek study area.

The study stream contains a native fish community composed of resident and searun cutthroat trout (_Salmo clarki_), and prickly sculpin (_Cottus asper_). Escapement of other anadromous salmonids into the study area is prohibited by a small waterfall and log jam located downstream of the study reach. The barrier allows upstream migration of adult cutthroat trout, but restricts larger fish, i.e., coho salmon and steelhead trout.

STUDY BACKGROUND

The information reported in this dissertation was collected in conjunction with a larger study investigating the impact of streamside timber removal on cutthroat trout and the stream ecosystem (Martin et al. 1981) and some of the conclusions stated in this dissertation are different from those previously reported. This dissertation covers the results of effects of canopy removal on trout and their food supply; whereas, the effects of canopy removal on primary production, detrital input, and benthic macroinvertebrate community structure were presented in Martin et al. (1981) and White (1981). The effects of canopy removal on fish habitat and the life history of cutthroat trout were addressed in Martin et al. (1981) and June (1981).

MATERIALS AND METHODS

EXPERIMENTAL DESIGN AND TREATMENT

A 1,200 meter section of Bear Creek was selected for study with the lower 1,000 meters of the reach designated as the "treatment zone" and the upper 200 meters as the "control zone" (Fig. 2). The treatment zone was subdivided into two 500 meter long sections and designated as the lower and upper treatment zones. The water surface area during the summer low flow period was 1,362 m^2, 1,240 m^2, and 638 m^2 for the lower treatment, upper treatment, and control zones, respectively.

The study was conducted from spring 1977 through summer 1980. Physical and biological parameters associated with cutthroat trout production were investigated during 1977 and 1978 (pre-treatment period) in designated treatment and control zones. Then riparian vegetation was removed from the treatment zone, carefully avoiding direct stream disturbance, and both zones were monitored during 1979 and 1980 (post-treatment period).

In February 1979, all timber within the treatment zone (60 meters wide on the southwest side of the stream and 10 meters wide on the northeast side of the stream) was felled except for some selected trees and non-merchantable timber (mostly red alder) within an 8-meter wide zone on both sides of the stream. The wide cut was located on the southwest side of the stream in order to maximize stream exposure to solar radiation. Trees considered critical for streambank protection, including woody understory vegetation within the 8-meter wide zone on both sides of the stream, were not removed in order to minimize physical disturbance to streambanks and the riparian area. This was accomplished, for the most part, through the use of skilled timber cutters and directional felling methods. Any debris (slash) that had

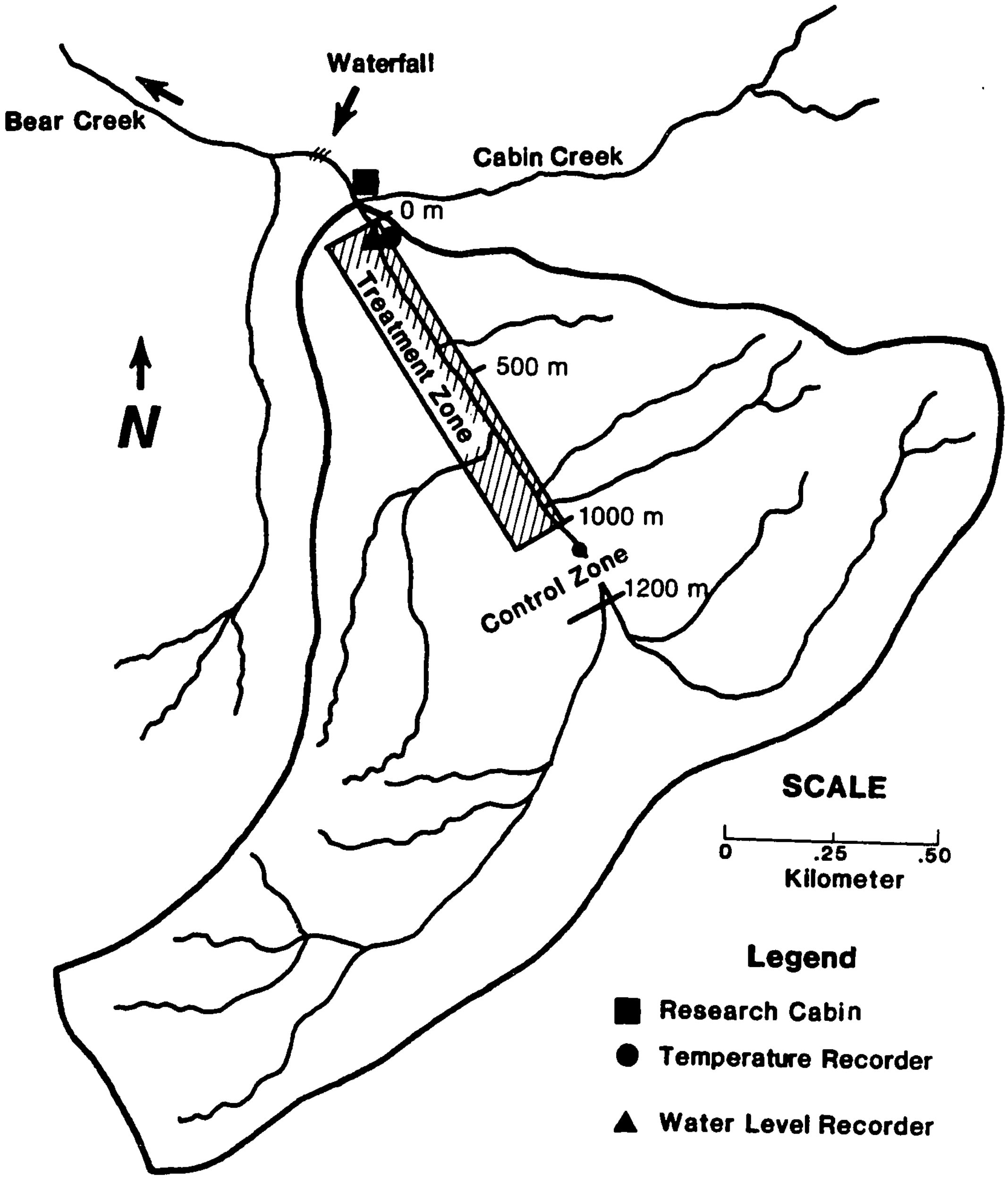

Figure 2. - Upper Bear Creek watershed and study area.

fallen into the stream was removed and placed out of the floodplain. Downed timber remained on the ground during the post-treatment period and was removed following the study in 1981.

PHYSICAL ENVIRONMENT

Water Temperature

Water temperature was recorded in the treatment and control zones by Weather Measure Model T601 temperature recorders. Recorders were operated continuously, except during some winter months, from spring 1977 through summer 1980 at stations 100 and 1125 (Fig. 2). Station locations refer to the distance along the study reach measured in meters. A temperature recorder was also operated during spring and summer of 1979 at station 675 (upper treatment zone). Hourly temperature measurements were entered on a computer file, and the maximum, minimum, and average temperatures for each station were computed and summarized on daily and monthly bases.

Temperature data for station 100 was available for all months except for a six month period during winter 1979-80. Data for this period were estimated from a linear regression equation that associates Bear Creek with Peterson Creek, a tributary of the Clearwater River (Fig. 2). Gaps in data for station 675 during 1979-80, and station 1125 during 1977-80 were estimated from linear regression equations developed with station 100. Data for station 675 that were missing for all of 1977 and 1978 were estimated by taking median temperatures from stations 100 and 1125. This estimate is supported by the results of an ANOVA test of weekly mean temperatures which indicated no significant difference exists between stations 100 and 1125 during the pre-treatment period (Martin et al. 1981).

Stream Discharge

Water level was recorded at station 100 with a Weather Measure Water Level Recorder from April 1977 through October 1978. Stream discharge measurements were conducted over a range of streamflows. A stage vs. flow relationship was developed with linear regression analysis of these data. Streamflow data for 1979 and 1980 were estimated from a relationship between Bear Creek and the USGS discharge monitoring station located on the Calawah River (Fig. 1) near Forks. Discharge was also measured at station 1125 during summer base flow conditions and was compared to discharge at station 100 in order to determine the amount of water entering the study reach from tributaries and seeps.

FISH FOOD SUPPLY

Benthos

Benthic macroinvertebrates were sampled with a modified Neill cylinder (Neill 1938). It samples a 0.1 m^2 area and has a 0.233 mm mesh net. Four replicate samples were collected from three separate riffles at monthly intervals from March through October in 1978 and 1979. Sample sites were located at station 85 (lower treatment zone), station 850 (upper treatment zone), and station 1175 (control zone). Benthos samples were preserved in 70 percent ethanol and processed in the laboratory under a 7x - 30x variable power dissecting scope. Organisms were sorted into 3 mm size groups, enumerated, and the group wet weights measured after blotting on a dry paper towel. Mean density ($no.m^{-2}$) and biomass (mgm^{-2}) were computed from the four replicate samples for each month.

Monthly production of benthic macroinvertebrates was estimated from the biomass data by:

$$P_{monthly} = \frac{\overline{B}_{monthly} \cdot P/\overline{B}}{12} ,$$

where: P = production

$\overline{B}$ = average biomass

$P/\overline{B}$ = annual production to biomass ratio (i.e., turnover ratio, Waters 1969)

A turnover ratio of 5.2 was used to compute estimates of benthic production in Bear Creek. This turnover ratio was derived from production data developed by Martin (1976) (Appendix Table 1) in a study of benthic macroinvertebrate production in four tributary streams of the Clearwater River (Fig. 1). Riparian vegetation along the four streams represented conditions in an old-growth, second-growth, and clearcut forest. Invertebrate taxonomic composition and life history patterns in these streams were assumed to be similar to benthos populations in Bear Creek.

Insect Fallout

Terrestrial insect fallout was sampled by 36 circular water traps that were placed randomly throughout the study area (i.e., 14 traps in the lower treatment zone, 16 traps in the upper treatment zone, and 6 traps in the control zone). The traps consist of an opaque colored plastic wash basin, 27 cm in diameter by 10 cm deep, with a screened overflow vent located 7 cm above the bottom. Traps were mounted approximately 30 cm above the stream surface on rebar posts and were filled with a 3 percent formaldehyde solution and 2 drops of dish detergent. The formaldehyde preserved insects that were trapped in the solution and prevented bird predation. The detergent acted to break the surface tension of the solution, causing insects that landed or fell on the surface to sink to the bottom of the trap.

Fallout traps were operated continuously for one or two one-week periods each month from May through August in 1978 and April through October in 1979. At the end of each sample period, all insects caught in each trap were enumerated, and placed in one of three storage containers designated for the treatment and control zones. Samples were preserved in 70 percent ethanol and processed in the laboratory under a 7x - 30x variable power dissecting scope. Organisms were sorted into 3 mm size groups and the group wet weights were measured to the nearest 0.1 mg after blotting on an absorbent towel. The fallout rate (no.$m^{-2}d^{-1}$ or $gm^{-2}d^{-1}$) was computed as a the product of the total number or biomass caught in a trap, and 17.47 (area conversion to m^2) divided by the number of days the trap was in operation. Total biomass of insect fallout for each month was computed from the product of the average fallout rate ($gm^{-2}d^{-1}$) and the number of days per month.

FISH POPULATION STUDIES

Population Estimation

Population size and biomass were computed from population census data that were collected during July and October 1977; April, July, and October in 1978 and 1980; and in April, May, July, August, and October in 1979. Trout were captured with a backpack electroshocker and all fish were anesthetized with tricainemethane-sulfonate, weighed on a dial-a-gram balance to the nearest 0.1 g, and fork length was measured to the nearest 1.0 mm. Age structure of the population was determined from scales and from analysis of the length frequency distribution.

Population estimates were computed for each age group by the Petersen mark-and-recapture method as modified by Chapman (1951):

$$N = \frac{(m+1)\ (c+1)}{r+1},$$

where: N = estimated number of fish in population
m = number of marked fish in population
c = number of fish in sample
r = number of marked fish in c

The variance associated with this estimate is based on either a normal or a binomial distribution, as determined by Seber (1973):

$$p = r/c,$$

where: p and the number of fish in the sample (c) are compared against the values shown in the following table where the corresponding c values are the smallest values of c for which the normal approximation is applicable

when							
	p (or 1-P)	=	0.5	0.4	0.3	0.2	0.1
	c	=	30	50	80	200	600

If the number of fish in the sample (c) is greater than the c value associated with the calculated p, then a normal distribution is used to calculate a 95 percent confidence limits with variance from Seber (1973):

$$V(N) = \frac{(m+1)\ (c+1)\ (m-r)\ (c-r)}{(r+1)^2\ (r+2)},$$

and the 95 percent confidence level is $N \pm 2\ [V(N)]^{1/2}$,

where V(N) is the variance of N.

If the sample c is less than the tabulated c, then a binomial confidence limit for p was generated from the computer program BILBIN, which was obtained from the International Mathematical and Statistical Libraries. The lower and upper limits for p are substituted for r in the N estimation formula as follows:

$$\frac{(m+1)\ (c+1)}{p_u\ c + 1} < N < \frac{(m+1)\ (c+1)}{p_l\ c + 1}$$

where: p_u and p_l are the upper and lower limits for p from the binomial distribution

Biomass

Estimates of biomass for each age group of trout were computed as follows:

$$B = \bar{W}\ N,$$

where B is the estimated population biomass (g) and $\bar{W}$ is the estimated mean wet weight (g).

The 95 percent confidence limits for biomass were calculated for the normal distribution as:

$$95 \text{ percent confidence limit} = B \pm 2\ SE\ (B),$$

where

$$SE\ (B) = [\bar{W}^2\ V(N) + N^2\ V\ (\bar{W})]^{1/2}$$

and $V\ (\bar{W})$ is the variance of estimated mean weight $\bar{W}$.

The 95 percent confidence limits for biomass were calculated for the binomial distribution as:

$$B_{\text{lower limit}} = (N_{\text{lower limit}})\ (\bar{W}_{\text{lower limit}}),$$

and

$$B_{\text{upper limit}} = (N_{\text{upper limit}})\ (\bar{W}_{\text{upper limit}}).$$

Growth

The instantaneous population growth rate (G_x) was computed for each age group as:

$$G_x = \frac{\log_e W_2 - \log_e W_1}{\Delta t},$$

where W_1, W_2 are mean weights of fish at times t_1 and t_2.

Monthly instantaneous growth rates were computed from estimates of mean weight that were derived from growth curves (see method for production). This was used to estimate production on a monthly basis. Instantaneous growth rates were also converted to a daily relative growth rate ($mgg^{-1}d^{-1}$ wet weight) for the purpose of relating daily growth to daily consumption rate which was measured in the same units. Daily relative growth rate can be converted to percent weight/d by multiplying by 0.1.

Production

Production is defined as the total quantity fish flesh formed in the population during a given time interval, disregarding the survival rate over that period (Allen 1969). Production was computed by the method outlined in Chapman (1978), which assumes exponential growth and a linear change in biomass:

$$P = G_x \bar{B},$$

where P is the production for time interval (g, wet weight), and $\bar{B}$ is the average biomass for time interval.

Production was computed on a monthly basis for each age group (0 through III) and for each study zone during the period, July 1977 through September 1980. Data for population size and mean weight at the beginning of each month were derived from curves of both survivorship and growth. These curves were plotted by hand on graph paper, taking into account confidence limits and time of year, similar to the method utilized by Chapman (1965). Confidence limits for production could not be computed because no statistical technique is available for calculating standard errors for lines fitted by eye (Chapman 1965).

FISH FOOD CONSUMPTION AND PREY COMPOSITION

The food consumption and food habits of cutthroat trout in Bear Creek are based on stomach samples collected during 1978 from the lower treatment zone. Food consumption for each age group and study zone was estimated from the equation:

$$C = M + G,$$

where C is the daily consumption rate ($mgg^{-1}d^{-1}$, wet weight), M is the daily maintenance ration[a/] ($mgg^{-1}d^{-1}$, wet weight), and G is the relative daily growth rate ($mgg^{-1}d^{-1}$, wet weight).

The daily maintenance ration was estimated with a regression model that was developed from in situ measurements of daily food consumption. Consumption measurements were determined for trout age 0 through age II at temperature levels ranging from 5° to 14°C during the period February 22 through November 11, 1978. Daily consumption estimates and daily maintenance ration (i.e., C-G) were entered as dependent variables in a stepwise multiple regression program, with temperature, mean weight, and population density as independent variables (data in Appendix Table 2). The results indicated that water temperature and mean weight accounted for 89 percent of the variation in the maintenance ration ($r^2 = 0.89$), significant at p 0.001. The relationship between these three variables was defined by the multiple regression equation:

$$\ln M = a + b_1 T - b_2 \bar{W}$$

where M is the daily maintenance ration, T is the mean daily temperature, W is the mean weight of fish, and:

$$a = 1.6493 \pm 0.5169$$
$$b_1 = 0.2409 \pm 0.0473$$
$$b_2 = 0.0584 \pm 0.0319$$

[a/] The maintenance ration in this case includes energy of active metabolism plus excretion.

In situ measurements of food consumption (Appendix Table 3) were computed by the modified Bajkov (1935) method:

$$C = 24SR,$$

where C is the daily consumption rate ($mgg^{-1}d^{-1}$, wet weight), S is the mean level of food in stomach during a 24-hour period (mgg^{-1}, wet weight), and R is the instantaneous rate of evacuation.

The mean level of food in a stomach was determined by removing stomach contents from trout of each age group at 4- to 6-hour intervals during a 24-hour period (see Appendix Tables 4 through 6 for estimates of S). Stomach contents were flushed from the foregut of live trout using the syringe technique described by Meehan and Miller (1978). Stomach samples were preserved in 70 percent ethanol, and then dried at 60°C for 24 hours. The dried contents were weighed to the nearest 0.1 mg and converted to wet weight using a 5:1 conversion ratio (IBP 1971). Consumption was expressed as a wet weight because all fish were measured live and returned to the stream. Evacuation rates were computed for the daily mean water temperature with the temperature equation developed for brown trout (Elliott 1972):

$$R = 0.053e^{0.112T},$$

where T is the mean water temperature.

Attempts to develop an evacuation rate equation for cutthroat trout in Bear Creek by the serial removal of stomach contents during the nighttime was unsuccessful. Fish were found to feed at any time during the diel period, resulting in a large variation in the weight of stomach contents. Also, the large sample of fish needed to obtain an accurate estimate of stomach fullness was difficult to obtain from small populations.

Taxonomic composition and size composition of prey organisms were determined from a sample of trout stomachs that were selected from the food consumption samples prior to the dry weight analysis. Organisms from full or nearly full stomach samples were identified to the family or order level and the length of each individual was measured to the neast 1.0 mm. Organism weights were estimated by the length-to-weight conversion formula developed by Malick (1977).

An analysis of the proportion of each prey size in the diet to the proportion of each size group of organisms available from the benthos and insect fallout was performed with the electivity index of Ivlev (1962). Values for the electivity index E(I) ranged from -1, indicating prey avoidance, to positive infinity, indicating prey preference. Electivity values within the range -0.5 to 0.5 were considered not significant, whereas, values outside this range were considered to indicate a significant size preference or avoidance depending upon direction of the value.

STATISTICAL ANALYSIS

Differences among study zones and among years for water temperature and estimates of insect fallout, benthic macroinvertebrate populations, and mean weights of fish were tested with the analysis of variance (ANOVA) and Student-Newman-Keuls multiple range test (Norman et al. 1975). Nonnormal data (i.e., benthos and insect fallout) were corrected by a logarithmic (base ten) transformation prior to statistical analysis. Comparisons among fish population estimates computed by the mark-and-recapture method were tested with the Z statistic (Douglas G. Chapman personal communication):

$$Z = \frac{N_1 - N_2}{[V(N_1) + V(N_2)]^{1/2}} ,$$

where Z is the normal deviate, and N is the population estimate at time one and time two.

Comparison between all combinations of pairs of years were significantly different if $Z > 2.58$, which is equal to $p < 0.01$ (2-tailed test).

RESULTS

STREAM DISCHARGE

Seasonal trends in streamflow were similar during the four years, but the timing of winter peak flows and summer low flows varied from month to month (Fig. 3). Peak flows during the winters of 1976-1977 and 1978-1979 occurred during February or March, which was one to three months later than the other two winters. Similarly, the months of lowest streamflow varied between July to August for all four years. These differences in streamflow are not attributed to the treatment, but rather were assumed a result of natural fluctuations in weather.

TEMPERATURE

A test of water temperature data with ANOVA showed temperature had a moderate but significant increase in response to streamside timber removal ($p<0.05$). Weekly mean water temperature in the lower treatment zone averaged 2°C greater than the control zone during the summer (Fig. 4). During the warmest period, July 16 through August 31, the maximum daily temperatures in the lower treatment zone ranged from 14.8°C to 15.6°C before treatment (1977-1978) and 17.2°C to 17.3°C after treatment (1979-1980, Table 1). Daily temperature fluctuations after treatment were significantly greater ($p<0.05$) in the treatment zone compared with both the control zone and pretreatment period (Table 1).

During the summer, the maximum difference in temperature between Station 100 and Station 1125 was 2.1°C before treatment and 4°C after treatment. As expected, the difference in temperature within the study area after treatment increased with increasing distance downstream from the shaded control zone (Fig. 5). This resulted in the formation of thermal zones on warm summer days. The low temperature, transition,

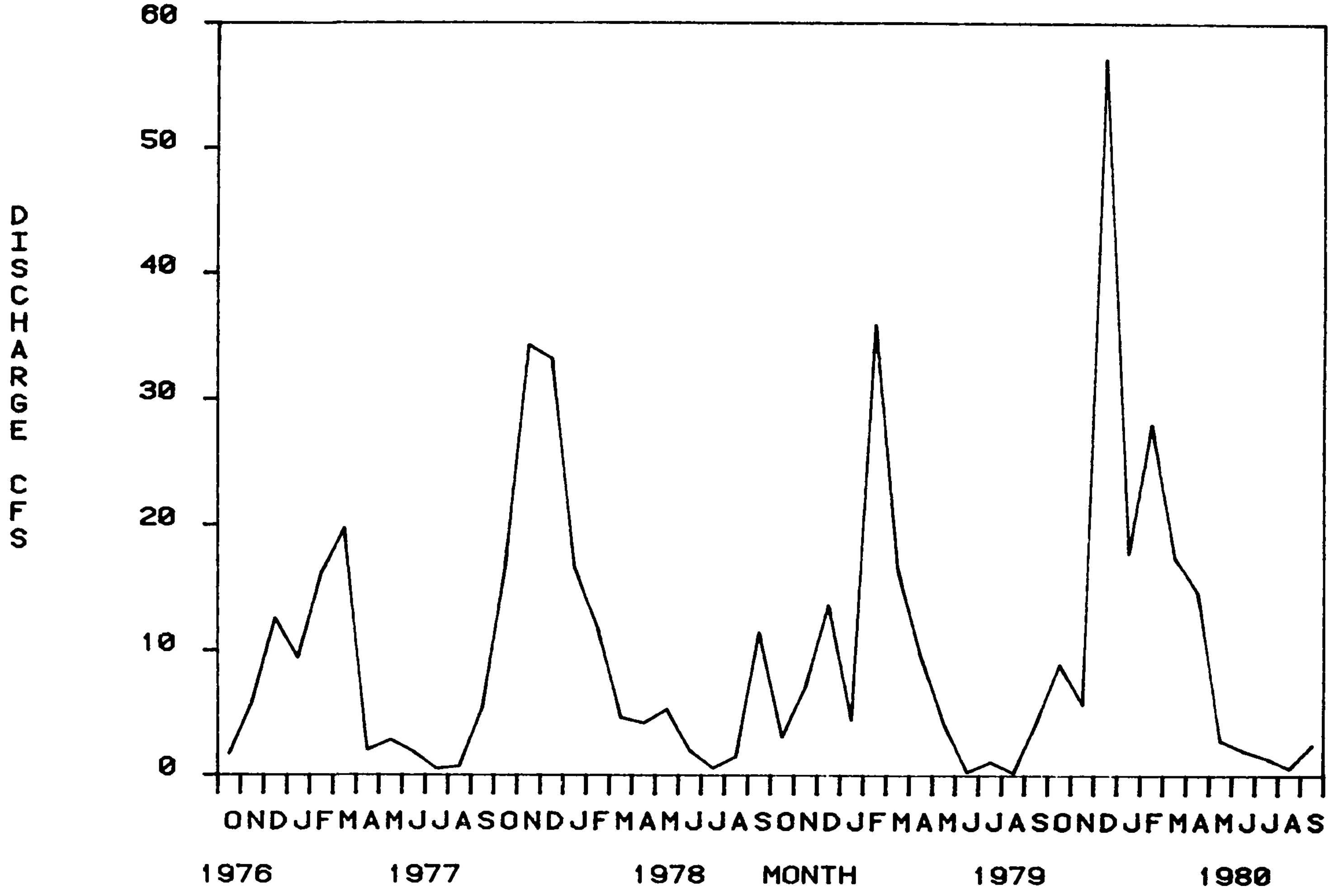

Figure 3 Mean monthly discharge (CFS) at station 100 of Bear Creek during 1977-1980.

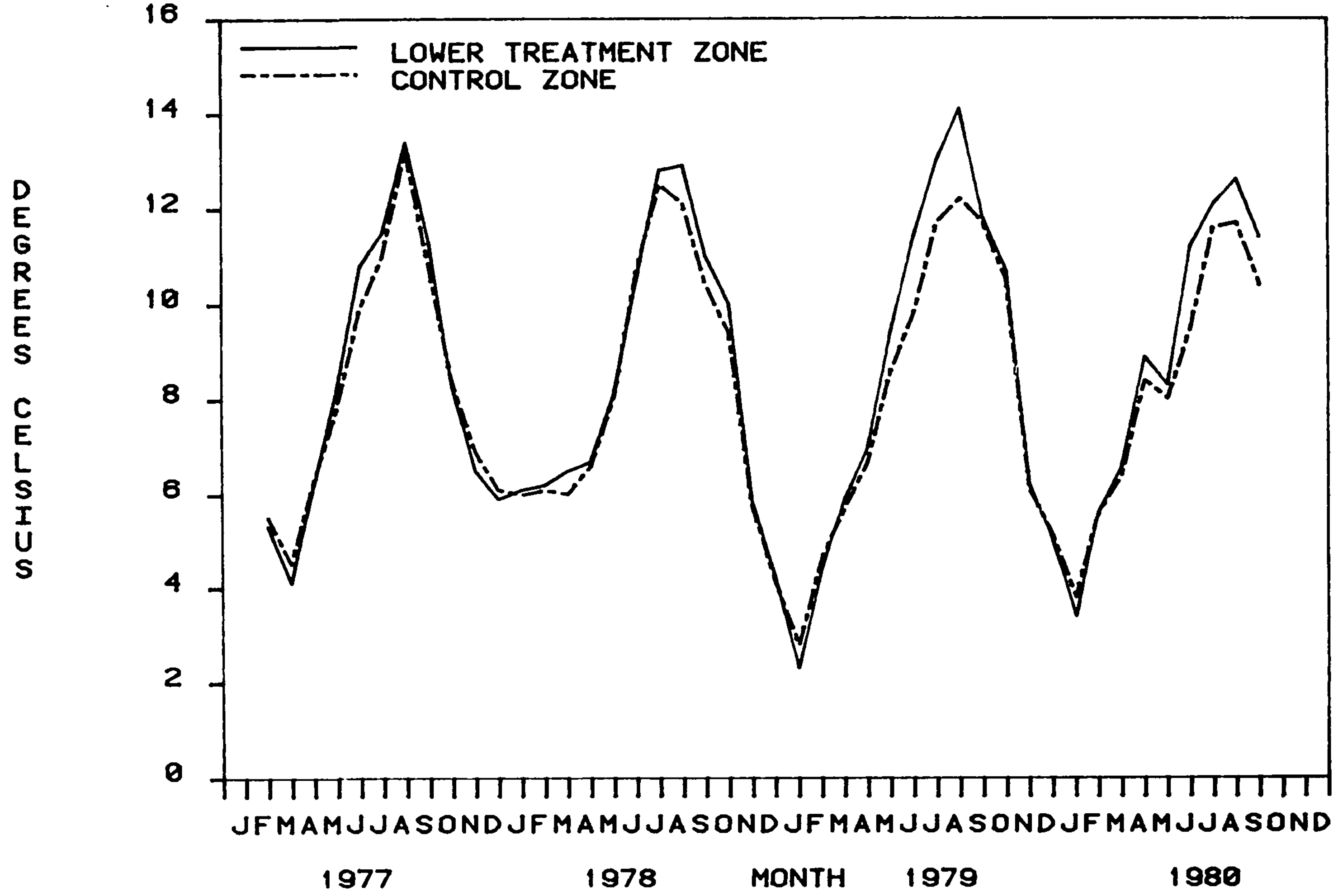

Figure 4 Monthly mean water temperature for the lower treatment zone (station 100) and control zone (station 1125) of Bear Creek, before (1977-1978) and after (1978-1980) streamside timber removal.

Table 1

Maximum water temperatures and daily temperature fluctuation statistics for the period of July 16 through August 31 in Bear Creek

Period/ Year	Lower Treatment (Station 100)					Control (Station 1175)				
	Max. Temp. (°C)	Diel Fluctuation (°C)				Max. Temp. (°C)	Diel Fluctuation (°C)			
		Max.	Mean	SD	N		Max.	Mean	SD	N
Pre-treatment										
1977	14.8	1.2	0.70	0.36	47	14.9	1.6	0.84	0.40	47
1978	15.6	1.4	0.71	0.37	46	14.6	1.4	0.77	0.32	45
Post-treatment										
1979	17.3	4.6	2.20	1.05	47	13.7	1.6	0.92	0.35	47
1980	17.2	5.5	2.51	1.47	47	13.0	1.4	0.61	0.32	28

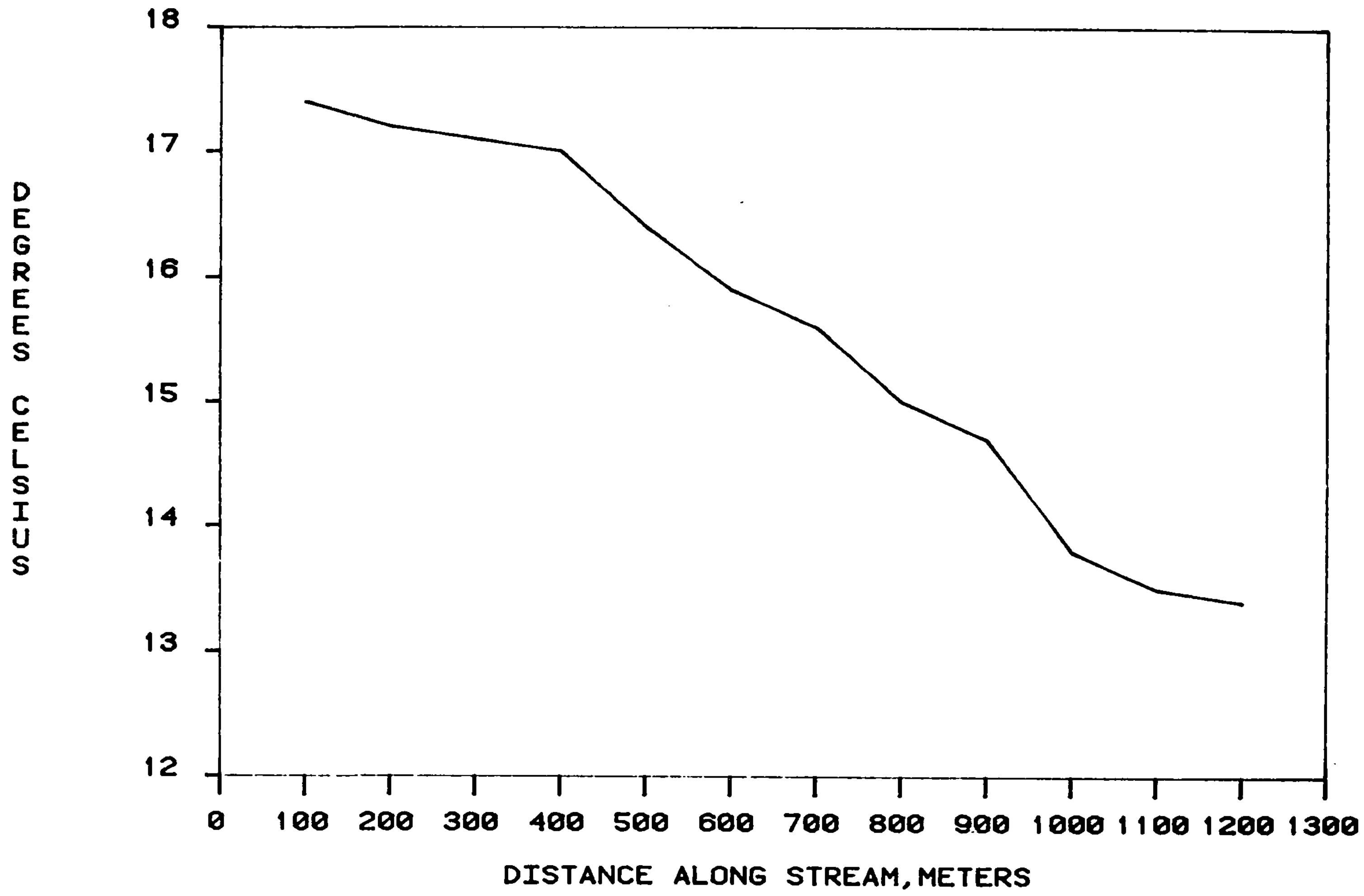

Figure 5 Longitudinal profile for water temperature in the treatment and control zones of Bear Creek on July 18, 1979, the warmest day of the year. Temperatures measured during the warmest time of day, i.e. 14:45-16:15.

and high temperature zones were formed in approximate correspondence with the control, upper treatment, and lower treatment zones, respectively. A longitudinal profile for temperature was not measured before treatment, but most likely consisted of a transition type profile extending throughout the entire study reach.

Total temperature units (TU = sum of daily mean temperature above freezing) accumulated in the treatment zone during the seven-month period April through October increased by an average of 165 TUs after treatment (Table 2). Differences in TU accumulation between the treatment and control ranged from 71 to 74 TUs before treatment and 194 to 270 TUs after treatment. The greater TU difference after treatment occurred as a result of greater TU accumulation in the treatment zone during the late-summer to fall period.

The temperature of water input from tributaries and seeps along Bear Creek was cooler than water in the main stream and contributed 43 percent of the total discharge (measured at Station 100) during the summer low flow period. For example, the temperature of inflow water on July 19, 1979 (warmest day of year) from tributaries located at Stations 900, 800, and 650 (Fig. 2) were 0.6°, 0.8°, and 2.1°C lower, respectively, than the main stream water temperature at these locations. The buffering effect of cool water inflow appears to minimize the thermal response of Bear Creek to riparian changes.

INSECT FALLOUT

Density and Biomass

Seasonal trends in the density of insect fallout followed a unimodal pattern (Fig. 6) with the peak fallout rate occurring during June and

Table 2

Monthly cumulative temperature units for the seven-month period, April through October, in the lower treatment and control zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

Month	Year 1977	 1978	 1979	 1980
	Lower Treatment Zone (Station 100)			
Apr	187	202	212	272
May	441	453	503	523
Jun	765	769	844	827
Jul	1,121	1,165	1,246	1,248
Aug	1,535	1,564	1,682	1,604
Sep	1,874	1,893	2,035	2,003
Oct	2,128	2,202	2,359	2,301
	Control Zone (Station 1125)			
Apr	187	200	200	240
May	427	448	466	471
Jun	725	773	759	720
Jul	1,066	1,157	1,119	1,089
Aug	1,474	1,532	1,496	1,399
Sep	1,792	1,840	1,848	1,768
Oct	2,054	2,131	2,165	2,031

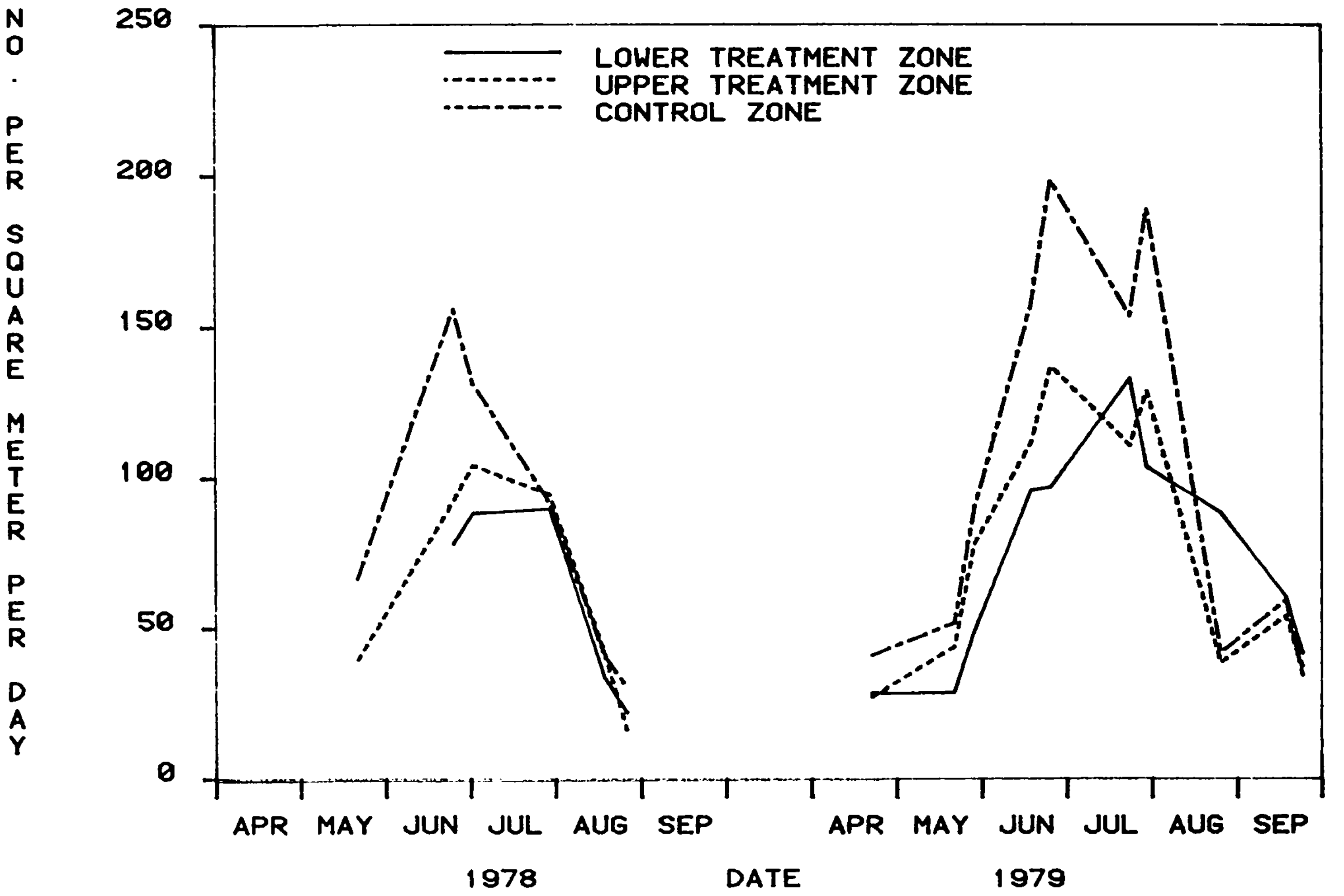

Figure 6 Mean insect fallout density (no.$m^{-2}d^{-1}$) in treatment (sections 0-500,500-1000) and control (section 1000-1200) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

July. Fallout ranged from 16 insects $m^{-2}d^{-1}$ during August to 198 insects $m^{-2}d^{-1}$ during June. No changes in this pattern were apparent as a result of the treatment.

A comparison of fallout rates (tested using ANOVA with data transformed logarithmicaly). Variations within years among zones indicated that densities (from Appendix Table 7) were significantly greater ($p = 0.006$) in the control zone than in the treatment zones during the pre-treatment period, but all three zones were not significantly different ($p = 0.309$) during the post-treatment period. A significant interaction between zones and dates during the post-treatment period indicated that the lack of detectable difference between treatment and control zones is dependent upon the time of year. However, a visual comparison among zones (Fig. 6) in 1979 indicates that the relationship between the lower treatment zone and the other zones changed somewhat compared to 1978. Densities increased in the lower treatment zone in July compared to the upper treatment zone, and increased in August compared to both of the other zones.

Insect fallout biomass could not be tested by the ANOVA because individual trap contents were not weighed. However, a plot of biomass (Fig. 7) indicates that biomass was reduced in all zones in 1979 and the monthly pattern of biomass among zones has changed. Biomass ranged from 84 $mgm^{-2}d^{-1}$ to 1,000 $mgm^{-2}d^{-1}$. Amounts of biomass in both treatment zones was similar or less than amounts in the control zone in 1978. Whereas in 1979, biomass in both treatment zones was greater than the control during April and May. Also, biomass in the upper treatment zone was greater than the control zone during late June and August. Biomass in the lower treatment zone was quite uniform throughout the year and did not show the summer peak, which was characteristic of the other zones. These results suggest that fallout biomass was changed by the treatment, and levels were increased for short periods in both treatment zones.

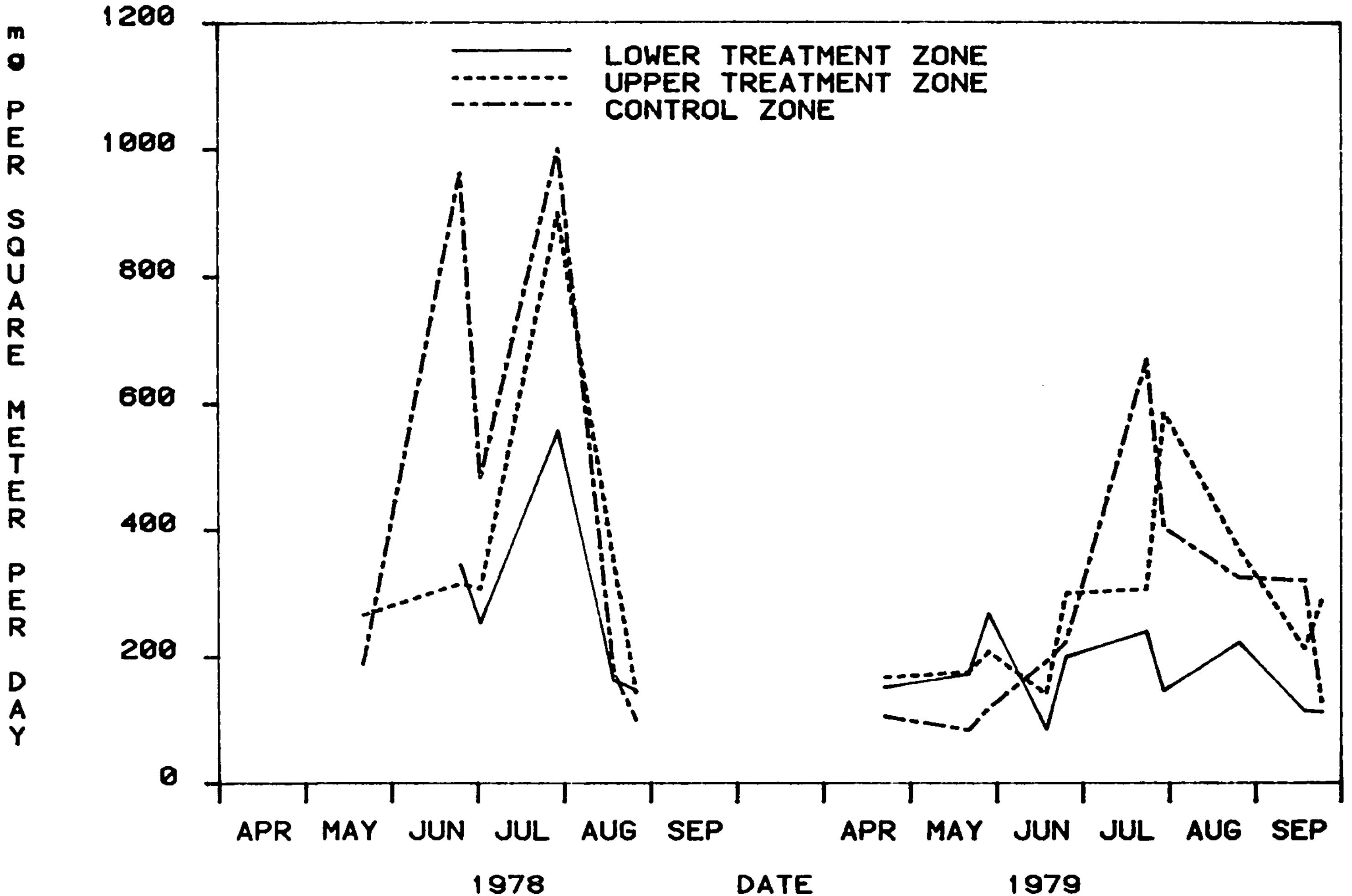

Figure 7 Insect fallout biomass (mgm^{-2}d^{-1}) in treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

Source

Greater than 80 percent of the insect fallout, on the average, was composed of Diptera, Coleoptera, and Araneae. However, during certain periods over 30 percent of the insect fallout was composed of adult aquatic insects (Appendix Tables 9 and 10). Therefore, any changes in the aquatic insect populations caused by the treatment could also have an affect on the density and biomass of insect fallout. In Bear Creek, the fallout of adult aquatic insects is greatest during spring, at a seasonal low during mid-summer, and increases in abundance during late summer-early autumn (Fig. 8).

Comparisons among zones within each year indicate that the percentage of fallout composed of aquatic insects was similar among all zones during 1978, but was different during 1979. Following treatment, the proportion of adult aquatic insects increased in both treatment zones during all months except April, late July, and August. These results suggest the density of aquatic insects may have increased as a result of the treatment.

The percentage of insect fallout biomass composed of adult aquatic insects followed a seasonal trend similar to the trends observed for density (Fig. 9). Biomass of aquatic insects ranged from 1 percent to 50 percent of the total fallout biomass. Comparisons between years indicates that biomass of aquatic insect was greater in 1979 than in 1978 for all zones, which was the opposite of the difference observed between years for total fallout biomass (Fig. 7). Comparisons of aquatic fallout biomass among zones within 1979 compared to within 1978 indicates that differences between the lower treatment zone and the other zones exist during the spring period. The lower treatment zone has a lower proportion of aquatic insect fallout relative to the other zones. These differences among zones and between years indicate that

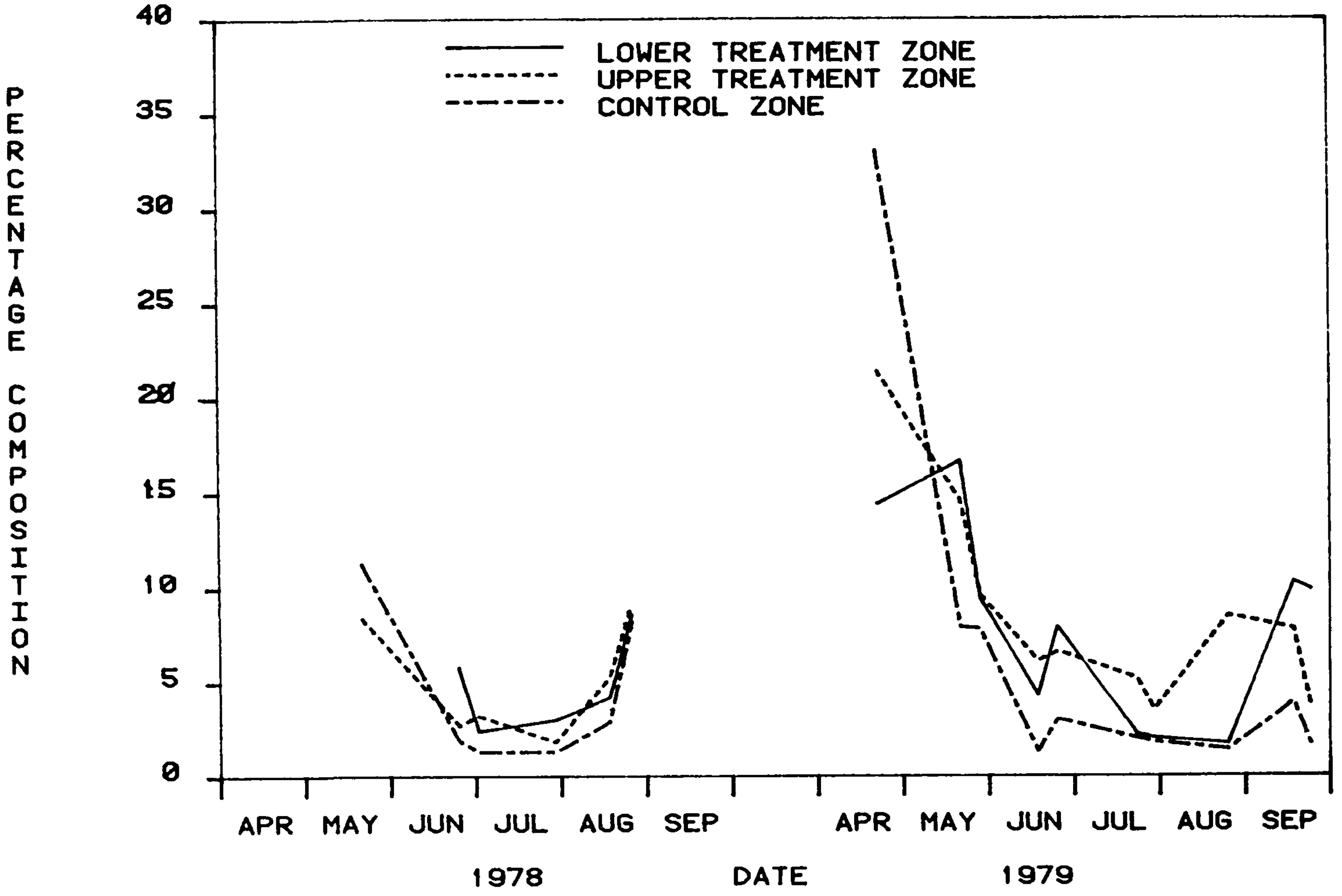

Figure 8 Percentage of insect fallout number (no.$m^{-2}d^{-1}$) composed of adult aquatic insects for treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1978) and after streamside timber removal.

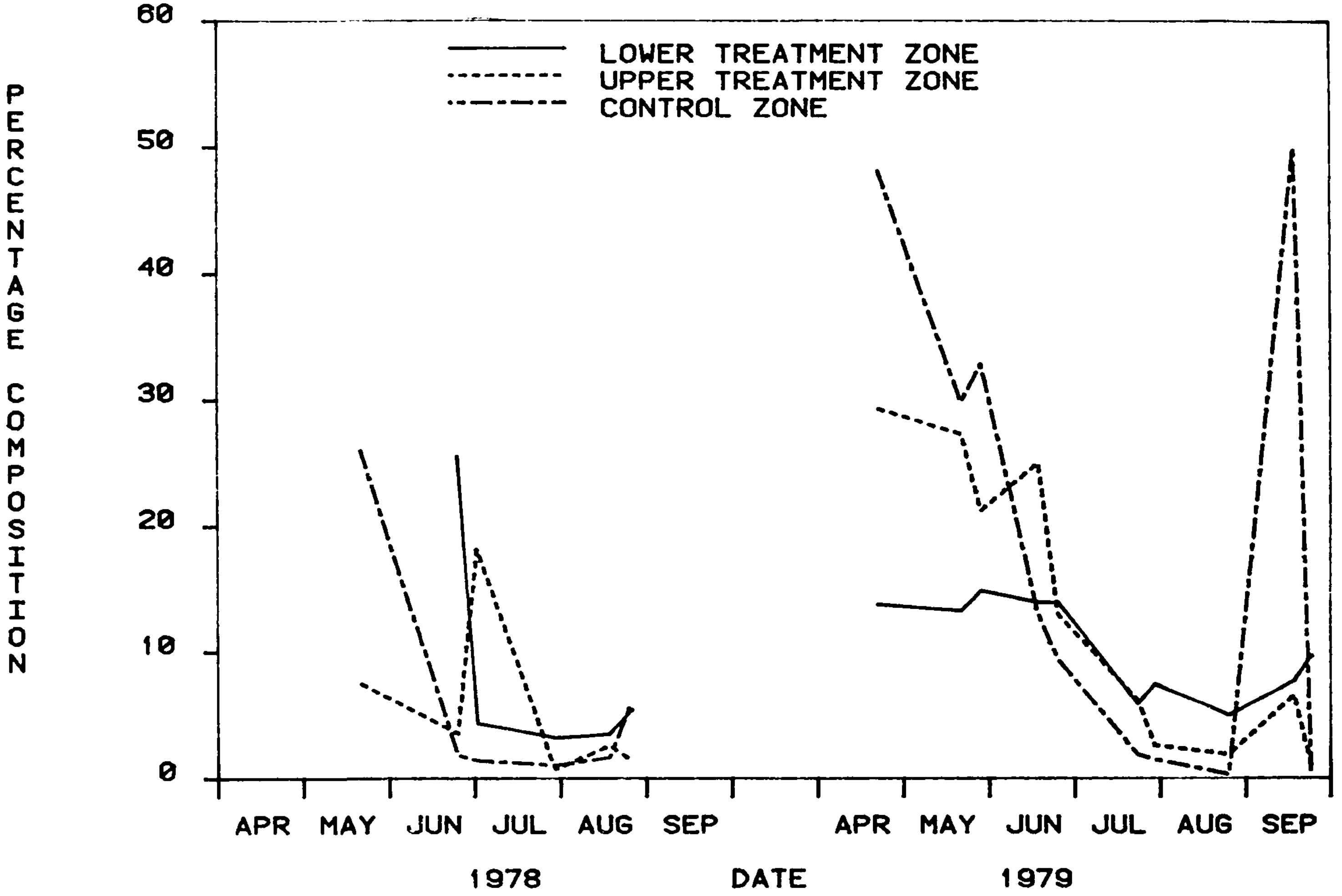

Figure 9 - Percent of insect fallout biomass (mgm^{-2}d^{-1}, wet wt.) composed of adult aquatic insects for treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

the total biomass of insect fallout would be significantly affected by changes in the contribution from adult aquatic insects. Therefore, the interpretation of the effects of the treatment on terrestrial insect fallout could be misleading.

An examination of the monthly input of insect fallout, less the contribution from adult aquatic insects, reaffirms the earlier conclusions concerning the effects of the treatment (Table 3). Prior to treatment, the total density of terrestrial fallout in the lower and upper treatment zones was 66 percent and 70 percent of the control zone, respectively. After treatment, the total density was 73 percent and 71 percent of the control zone, respectively. Thus, total density of terrestrial fallout increased in the lower treatment zone. Similarly, the relationship among zones within each year indicates that biomass was increased in both treatment zones relative to the control zone during 1979.

Size Composition

Approximately 80 percent to 90 percent of all insect fallout organisms were less than 6 mm long and contributed less than 50 percent of insect fallout biomass (Figs. 10 and 11). Small organisms (i.e., <6 mm) were most abundant during summer; whereas larger organisms were most abundant during spring and autumn. Comparisons between years indicates that a greater percentage of small organisms were present in 1979 compared to 1978 (Fig. 10). In 1978, an average of 54 percent of the individuals were less than 3 mm long, whereas in 1979, an average of 70 percent of the individuals were less than 3 mm long. This difference in relative size composition between years may account for the contrasting results of high density and low biomass of insect fallout observed for 1979 in Figures 6 and 7.

Table 3

Total monthly input of insect fallout, less adult aquatic insects[a], by number (no.m^{-2}) and biomass (gm^{-2}, wet wt.) for treatment (sections 0-500, 500-1000) and control (section 100-1200) zones of Bear Creek, before (1978) and after (1979) streamside timber removal

Median Sample Date	Month	Study Section					
		0-500		500-1000		1000-1200	
		no.m^{-2}	gm^{-2}	no.m^{-2}	gm^{-2}	no.m^{-2}	gm^{-2}
		Pre-treatment (1978)					
5-20	May	1,427 [c]	5.8 [c]	1,083	7.4	1,770	4.1
6-24	June	2,211	7.7	2,688	9.1	4,620	28.3
7-1, 7-28[b]	July	2,601	11.7	2,901	17.1	3,306	22.0
8-17, 8-25	August	785	4.4	815	7.3	1,010	4.0
Total (May-August)		7,024	29.6	7,487	40.9	10,706	58.4
		66% [d]	51%	70%	70%		
		Post-treatment (1979)					
4-21	April	732	3.9	645	3.6	822	1.6
5-20, 5-27	May	1,022	5.7	1,615	4.4	1,938	2.1
6-17, 6-24	June	2,715	3.7	3,492	5.5	5,221	5.6
7-24, 7-28	July	3,493	5.4	3,438	12.9	5,044	15.8
8-24	August	2,640	6.3	1,059	10.9	1,239	9.7
9-17, 9-23	September	1,374	3.1	1,277	7.3	1,362	4.3
Total (May-August)		9,878	21.1	9,604	33.7	13,442	33.2
		73%	64%	71%	102%		

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[a] Insect orders excluded are: Ephemeroptera, Plecoptera, Trichoptera.

[b] Input estimated from the mean of rates determined for more than one date per month.

[c] Estimated from the mean of sections 500-1000 and 1000-1200 for May.

[d] Percentage difference relative to values for the control zone.

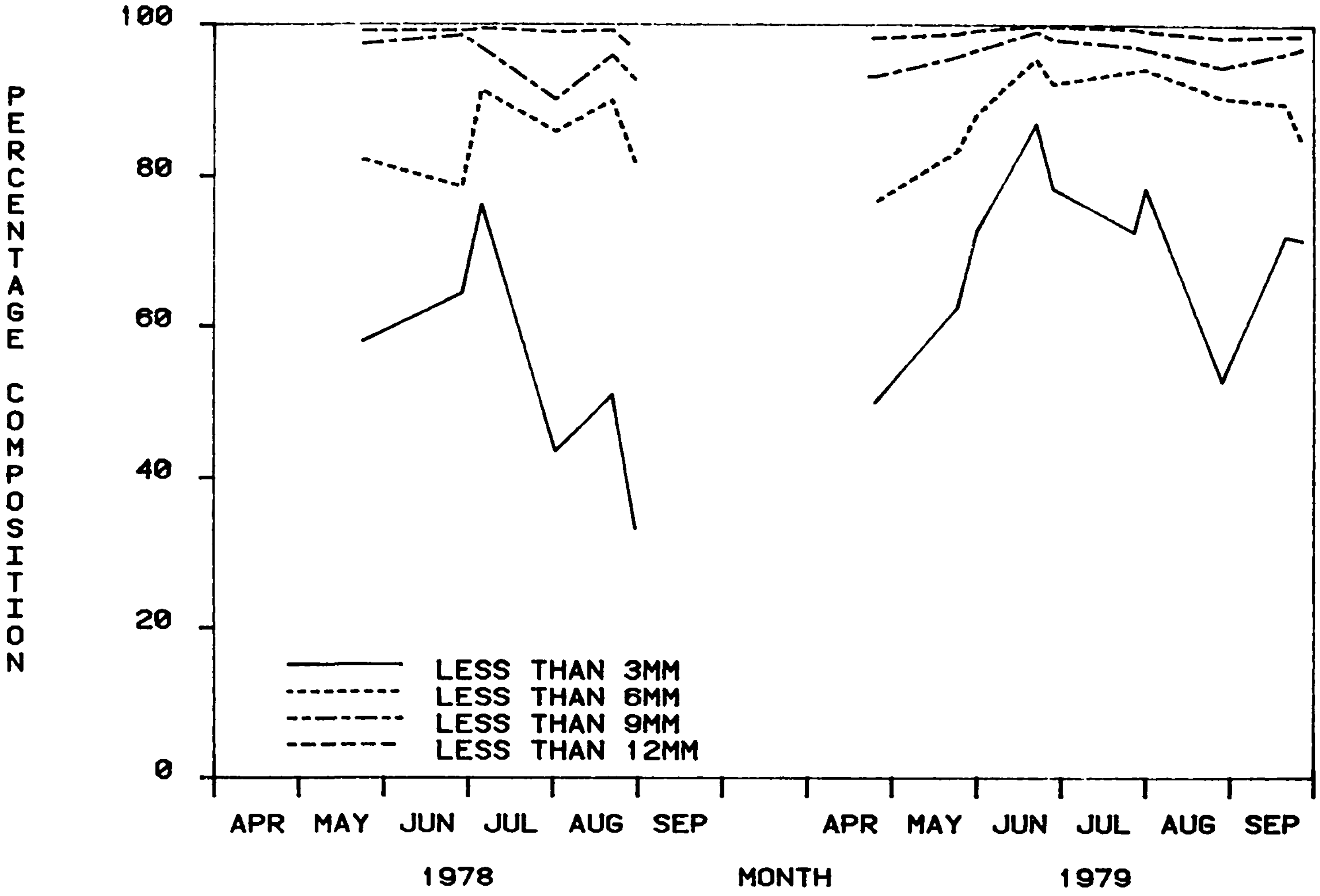

Figure 10 - Relative size composition of insect fallout for Bear Creek expressed as a percentage of total numbers for all study zones combine.

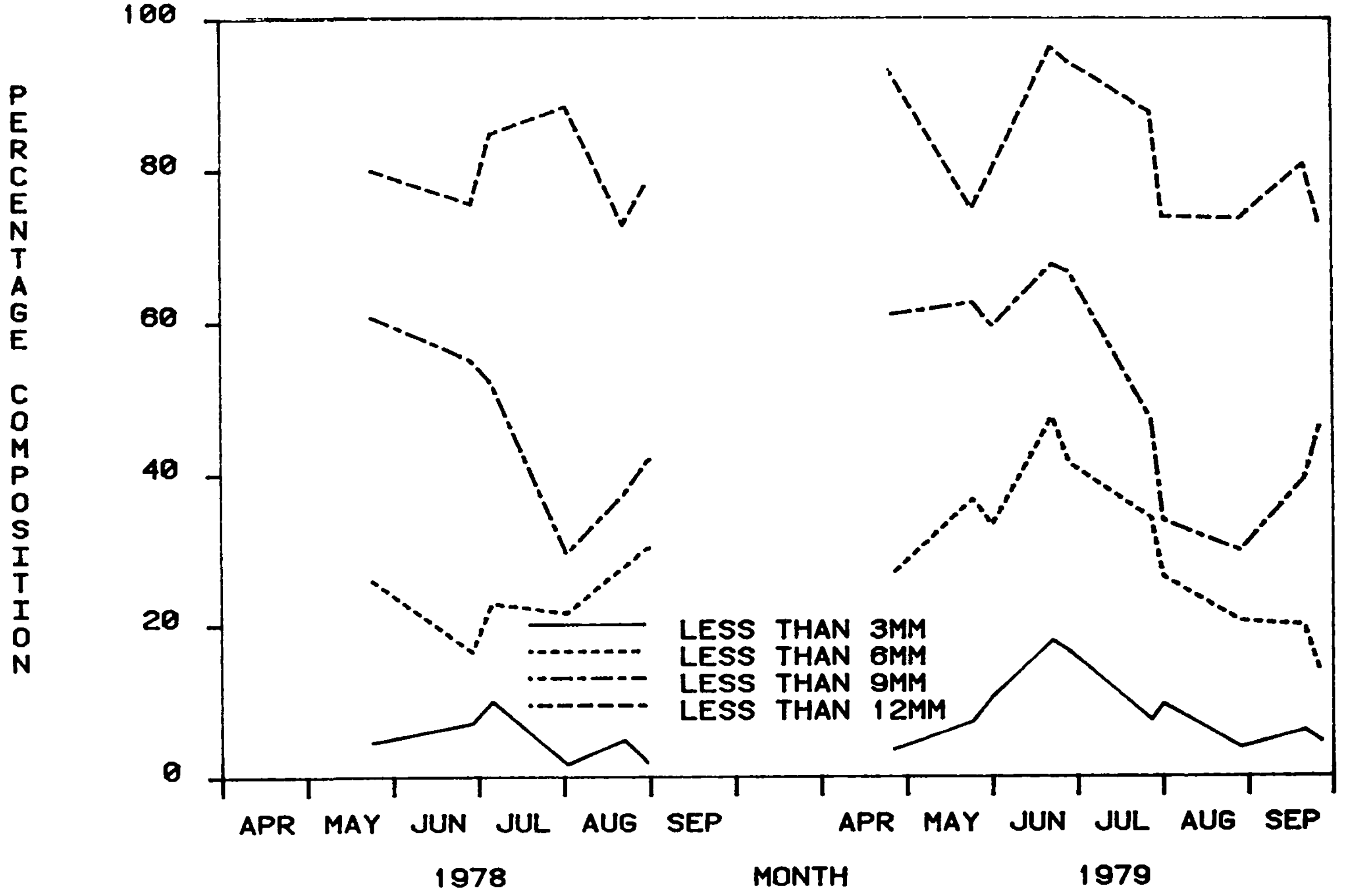

Figure 11. - Relative size composition of insect fallout for Bear Creek, expressed as a percentage of the total biomass for all samples combine.

BENTHOS

Density and Biomass

The benthic macroinvertebrate community in Bear Creek was primarily composed of aquatic insects of which 10 to 60 percent of the community were composed of larvae from the family Chironomidae. Mayfly and Stonefly nymphs from the families Baetidae, Heptagenidae, and Chloroperlidae were also very important, as well as caddisfly larva from the families Rhyacophilidae and Glyossosomatidae. The mean density and mean biomass of benthos are shown for all sample dates in Appendix Tables 11 and 12. The density at all three sample stations followed a seasonal trend of low numbers in late winter-spring, a sharp increase and peak density during mid-summer, followed by a gradual decline during the autumn (Fig. 12). Comparisons of density by ANOVA indicate that during 1978, density was significantly greater at Station 1175 than at Station 850, but there were no differences between Stations 85 and 850 or Stations 85 and 1175 (Table 4). Following treatment in 1979, densities at Stations 1175 and 850 were not significantly different, but they were both significantly greater than Station 85. Stations 1175 and 850 had a significantly greater ($p = 0.001$) density in 1979 than in 1978, whereas densities at Station 85 were not significantly different ($p = 0.663$) between years.

Seasonal trends in biomass followed a bimodal distribution with peaks in standing crop occurring during spring and autumn (Fig. 13). Statistical comparisons indicated no significant difference among stations during 1978, but biomass at Station 850 was significantly greater than at Stations 85 and 1175 during 1979 (Table 4). Station 850 had a significantly greater biomass in 1979 than in 1978 ($p = 0.036$), although biomass at Stations 85 and 1175 was not significantly different ($p>0.05$) between years.

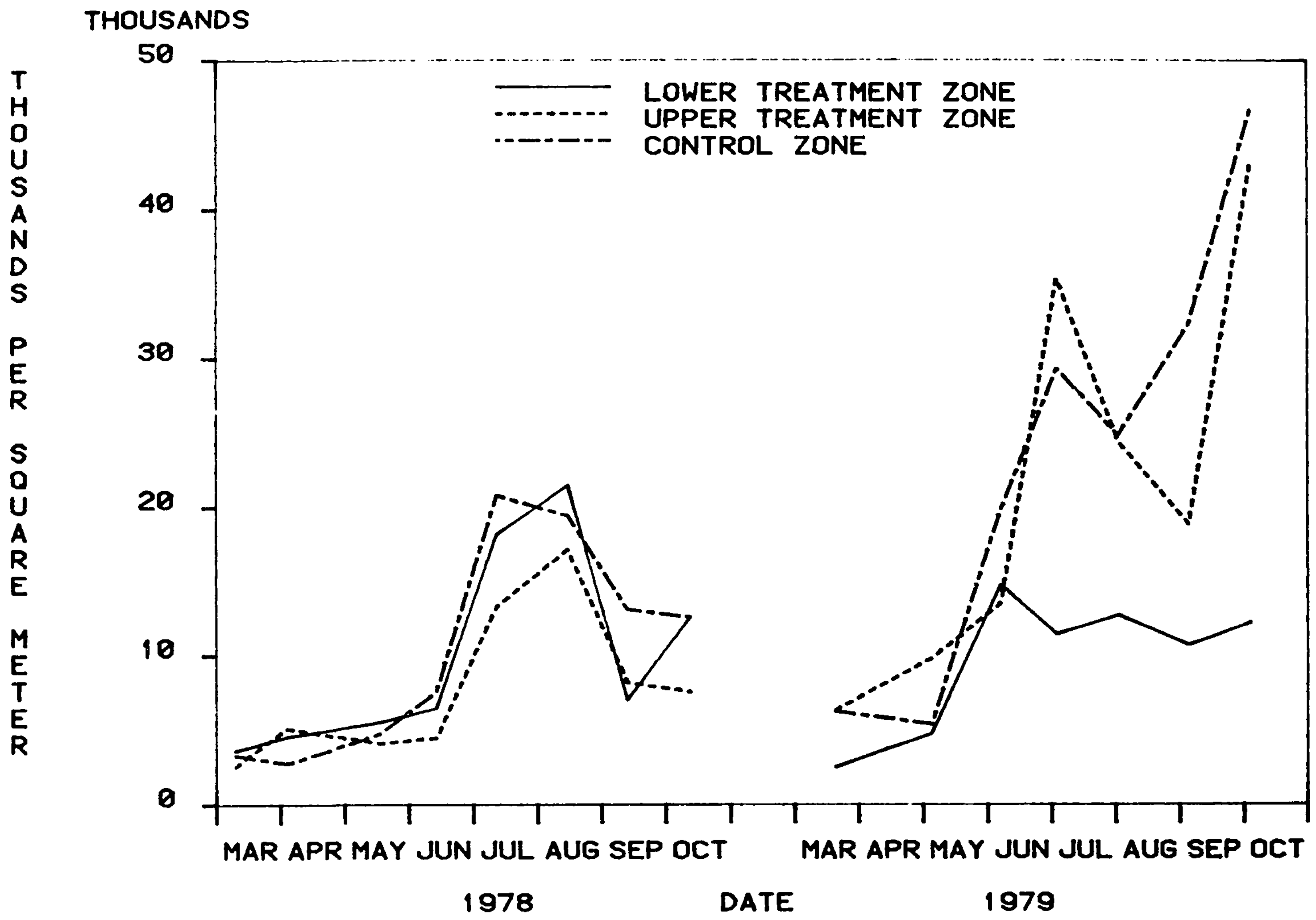

Figure 12 - Benthos mean density (no. m^{-2}) in the treatment (stations 85 and 850) and control (station 1175) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

Table 4

Results of ANOVA and multiple comparison tests on benthos density and biomass among treatment (stations 85 and 850) and control (station 1175) zones of Bear Creek, before (1978) and after (1979) streamside timber removal

	Density (no.m^{-2})				Biomass (gm^{-2})			
Year	Station/	Mean/	Similarity[a/]	Sig. of F	Station/	Mean/	Similarity	Sig. of F
1978	1175	85	850		85	1175	850	
	10502	9909	7777	.038	5.30	4.02	3.22	.052
	———	———			———	———	———	
		———	———					
1979	1175	850	85		850	85	1175	
	23458	21577	9840	.001	6.17	3.61	3.08	.034
	———	———			———			
			———			———	———	

[a/] Lines indicate similarity among stations.

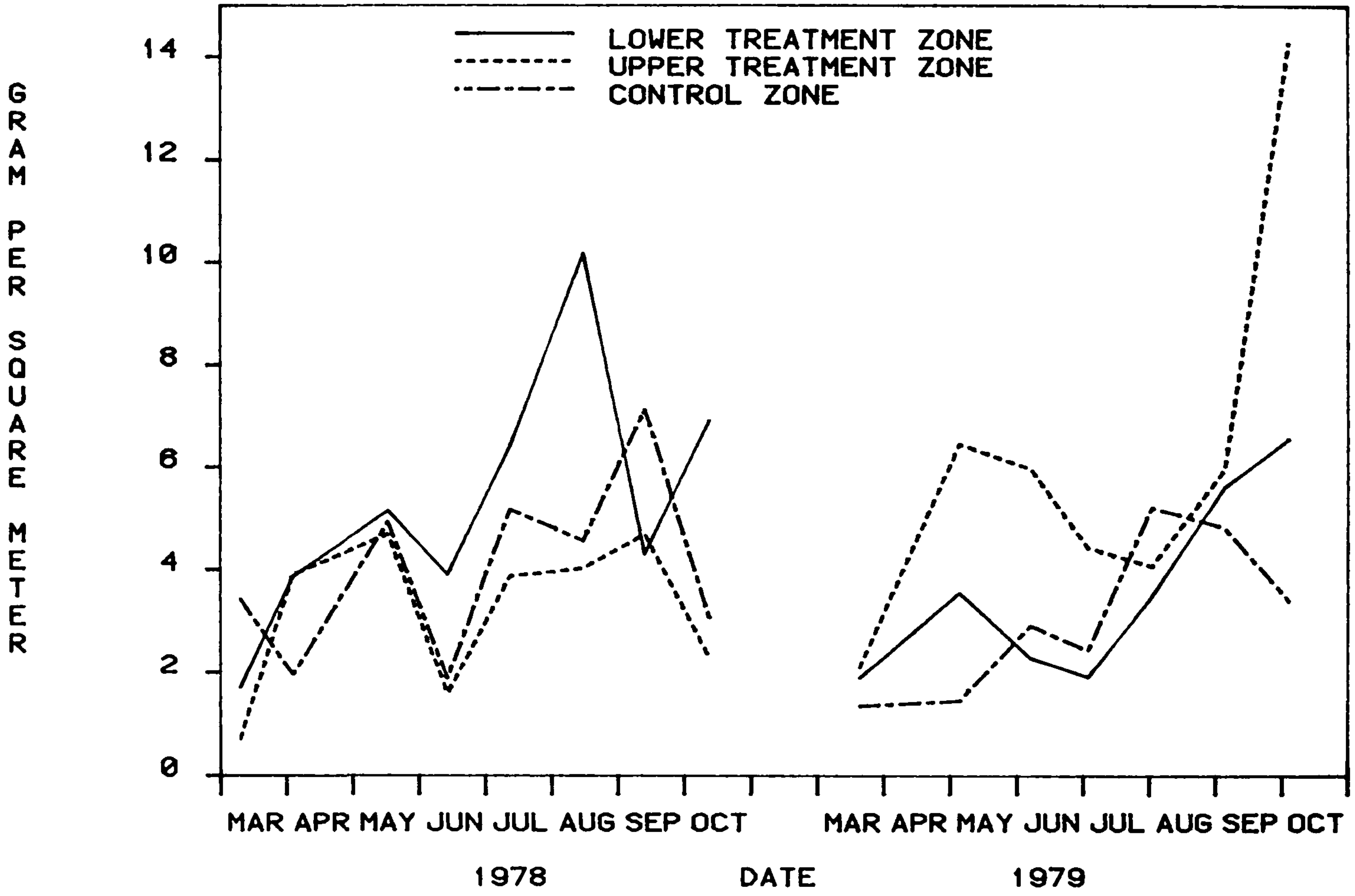

Figure 13 Benthos mean biomass (gm^{-2},wet wt.) in treatment (stations 85 and 850) and control (station 1175) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

Interpretation of benthos results requires an evaluation of the conditions of the benthos habitat at the three sample stations. The stream riffle sampled at Station 85 was significantly altered by winter freshets between 1978 and 1979. A partially embedded log at the downstream end of the riffle was undermined during a high flow, causing the stream to flow under the log, rather than over the log as was the case during 1977 and 1978. Riffle morphology changed from a broad uniform reach with shallow depth and low velocity to a more narrow, confined channel with greater depth and higher velocity. White (1981) measured the substrate particle size composition in 1978 and 1979. He found substrate size composition had shifted from predominately gravel toward a dominance of larger cobble size material. Also, small changes in channel morphology and substrate composition were observed in all three study zones as well. Station 850 did not change in morphology but had a moderate increase of smaller substrate (i.e., pea gravel) in the sample riffle. Station 1175 did not have a detectable change in benthos habitat.

Benthos habitat conditions at Station 85 are not comparable between years nor are they representative of benthic habitat within the lower treatment zone. Changes in habitat were assumed to have masked any effect canopy removal may have had on the benthic community. Therefore the response observed at Station 85 can not be attibuted to an effect of the treatment. On the other hand, channel morphology and substrate composition in other areas of the lower treatment zone was not greatly different from pretreatment conditions. It was possible that the abundance of benthos in these areas may have been affected by the treatment.

Benthic habitat conditions at Stations 850 and 1175 were assumed to be comparable between years. Benthos density at Stations 850 and 1175 increased significantly from 1978 to 1979, suggesting that conditions (e.g., weather) were more favorable in 1979 for both treatment and control zones. However, Station 850 in the treatment zone not only responded with increased density, but a significantly greater biomass during 1979. The results suggest that benthos density and biomass at Station 850 increased as a result of both weather and treatment effects.

Size Composition

The relative size composition of benthic organisms in Bear Creek varied from spring to autumn and the maximum length of most organisms was less than 6 mm (Fig. 14). Organisms less than 6 mm long accounted for 96 percent to 99 percent of all benthic organisms, and organisms greater than 6 mm long never accounted for more than 4 percent of the benthos population. On the contrary, organisms less than 6 mm long accounted for only 47 percent (average for 1978 and 1979) of the benthos biomass (Fig. 15). Thus, large organisms are rare, but the few large organisms present contribute the major portion of biomass to the benthic community. Note most of the large organisms were present during the late summer-fall period.

Production

The overall response of the benthic community to an increase in temperature and increased solar radiation is indicated by the changes in benthic production (Fig. 16). A statistical comparison among stations was not possible because no variance could be computed for this method of estimating production. However, a visual comparison among stations and between years suggests that production in the upper treatment zone was increased after the treatment. Production at Station 850 was equal to or lower than production at the other stations throughout 1978; whereas, production at Station 850 in 1979 was greater

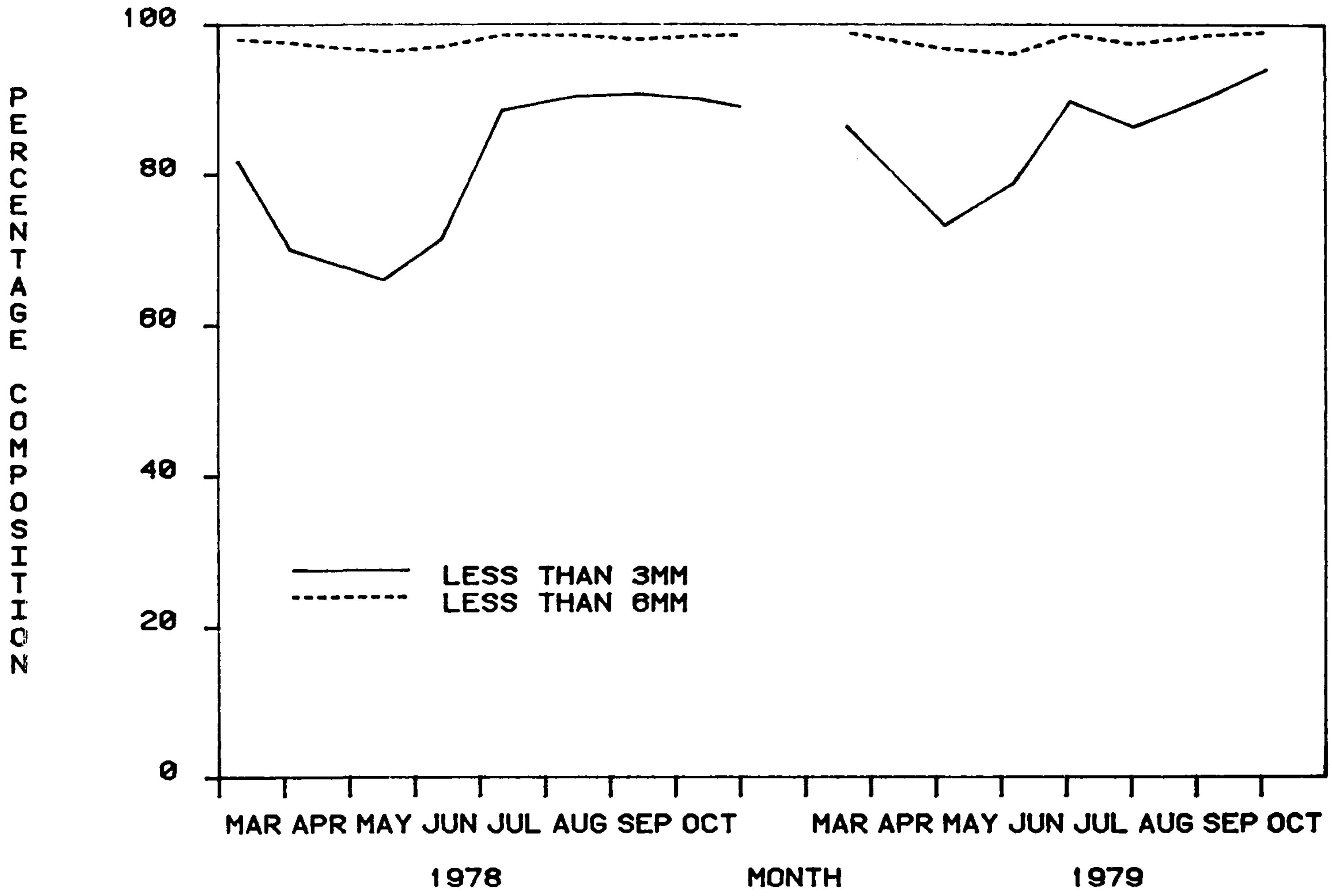

Figure 14 - Relative size composition of benthos for Bear Creek expressed as a percentage of mean density for all study zones combine.

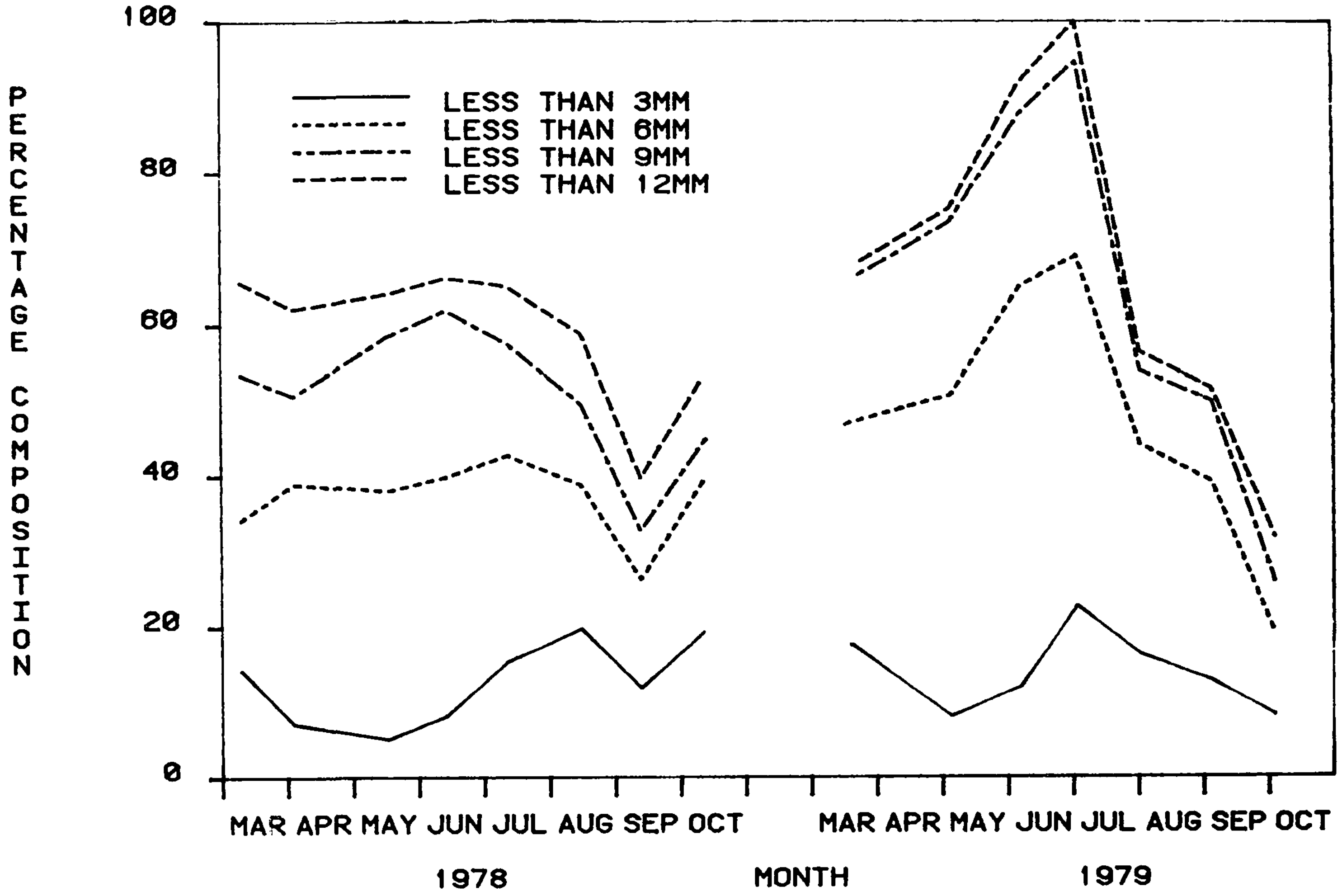

Figure 15 - Relative size composition of benthos for Bear Creek expressed as a percentage of mean biomass for all study zones combine.

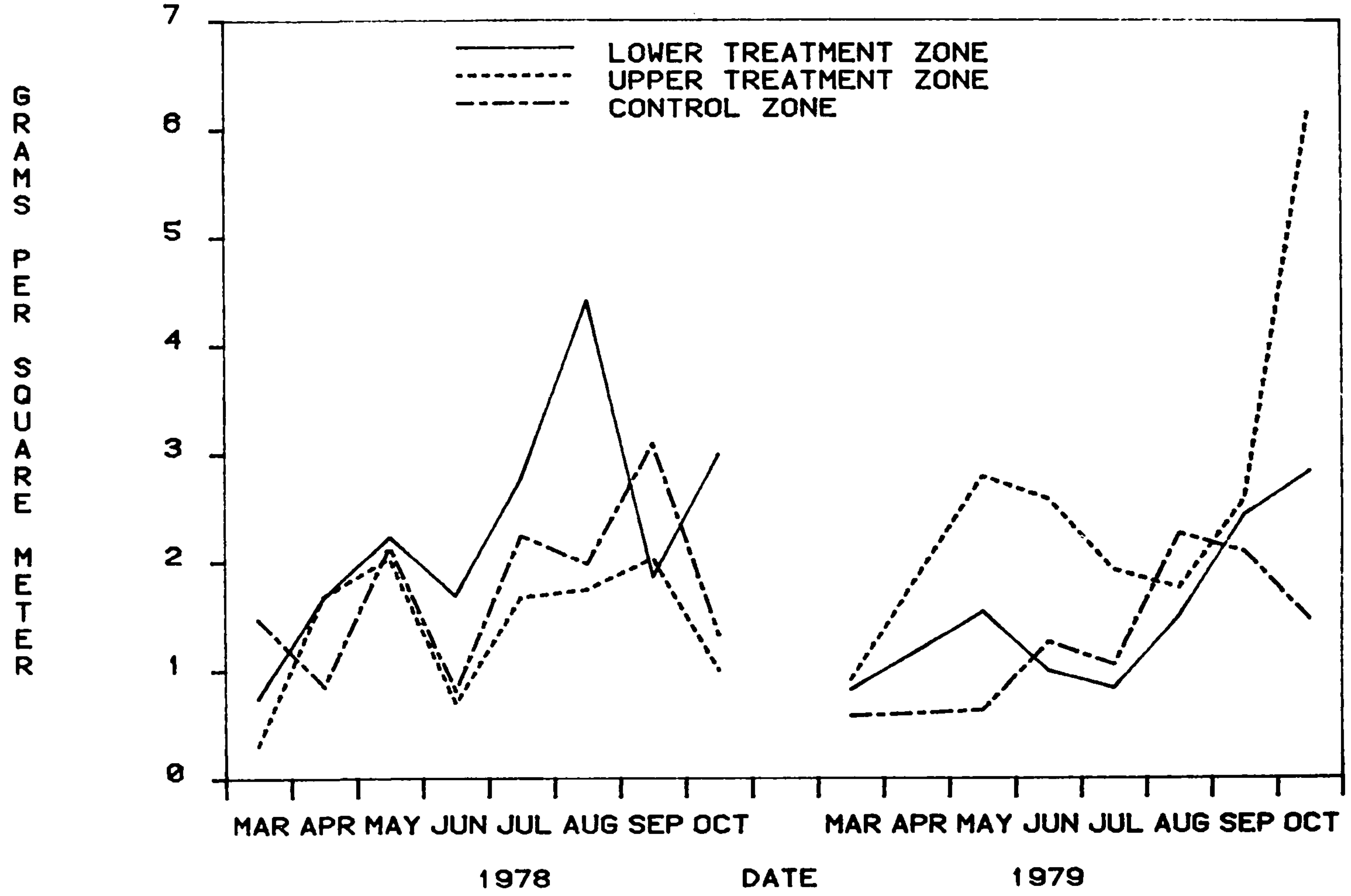

Figure 16 - Monthly production (g $m^{-2}mo^{-1}$) of benthic macroinvertebrates for treatment (stations 85 and 850) and control (1175) zones of Bear Creek, before (1978) and after (1979) streamside timber removal.

than the other stations for all months except August. Production in the lower treatment zone (Station 85) did not respond as strongly as did production in the upper treatment zone because of the habitat alterations described earlier.

During 1978, total benthic production for the period March through October at Statios 85, 850, and 1175 was 18.4 gm^{-2}, 11.2 gm^{-2}, and 13.9 gm^{-2}, respectively. After treatment, production at Stations 85, 850, and 1175 was 12.2 gm^{-2}, 20.6 gm^{-2}, and 10.0 gm^{-2}, respectively. Production at Stations 85 and 1175 had decreased by 34 and 29 percent, respectively; whereas production at Station 850 had increased by 84 percent.

FOOD CONSUMPTION

Consumption rates were computed for age 0 through age III cutthroat trout (Appendix Tables 14-16), of each study zone during all months when mean temperature (Appendix Table 13) and mean weight (Figures 22-24) data were available. Note, the consumption rate predicted for age III trout required extrapolation from a regression equation based on smaller fish (i.e., age groups 0 through II). However, the regression coefficient for weight was small (see methods for food consumption) and the functional relationship between consumption and weight holds for fish of any size (Brett 1979). Thus, any error created by extrapolation was assumed minor.

Consumption rates ranged from 0 to 146 mg $g^{-1}d^{-1}$. (Figs. 17, 18, 19, and 20). Rates were highest for age 0 cutthroat (Fig. 17) and declined with increasing age (i.e., mean weight). Comparisons among study zones before and after treatment indicate that the magnitude of a response to the treatment is variable and depends upon age group and year. Differences in consumption rate among study zones were greatest

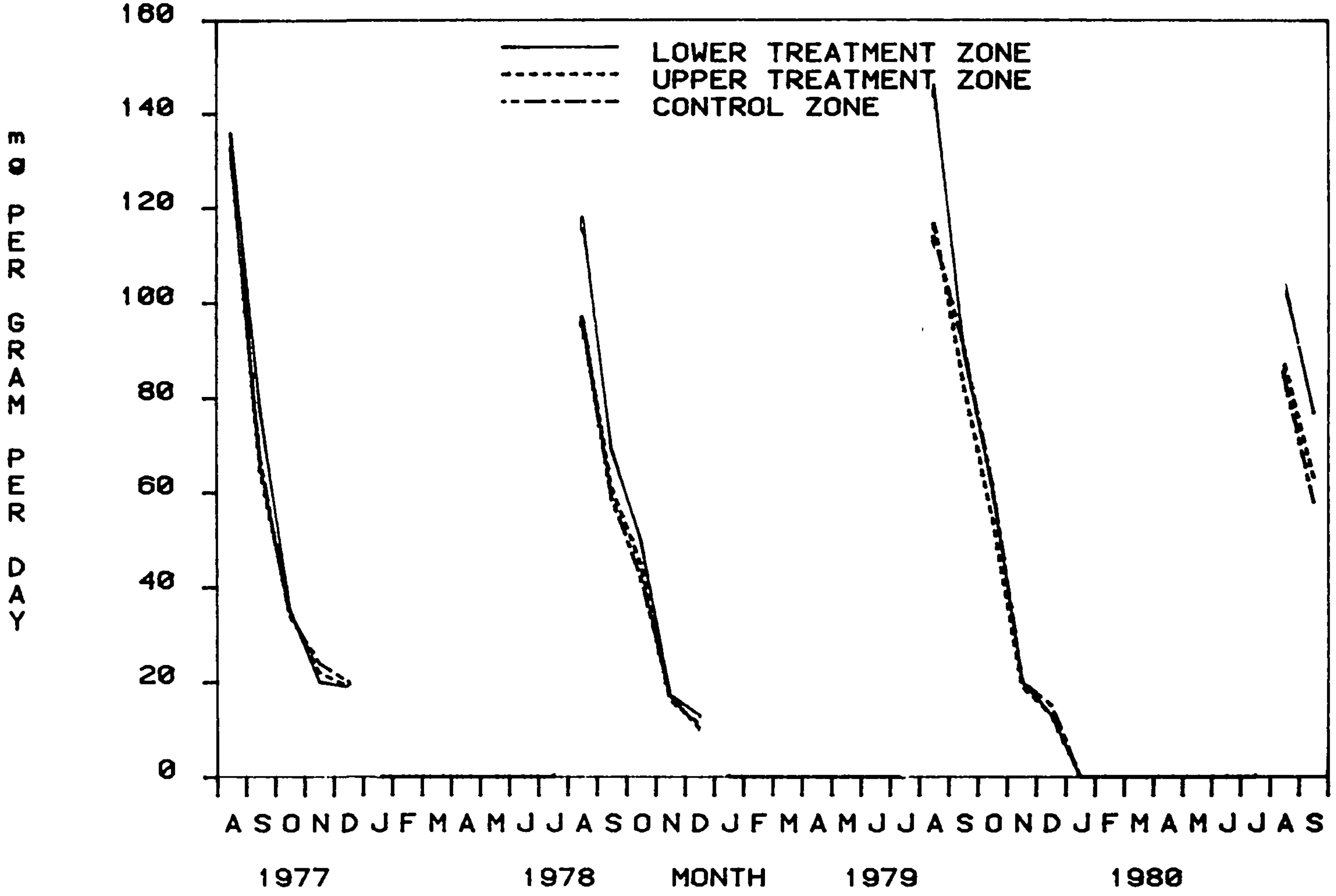

Figure 17 Mean daily consumption rate ($mgg^{-1}d^{-1}$) of age 0 cutthroat trout for treatment (sections 0-500,500-1000) and control (sections 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

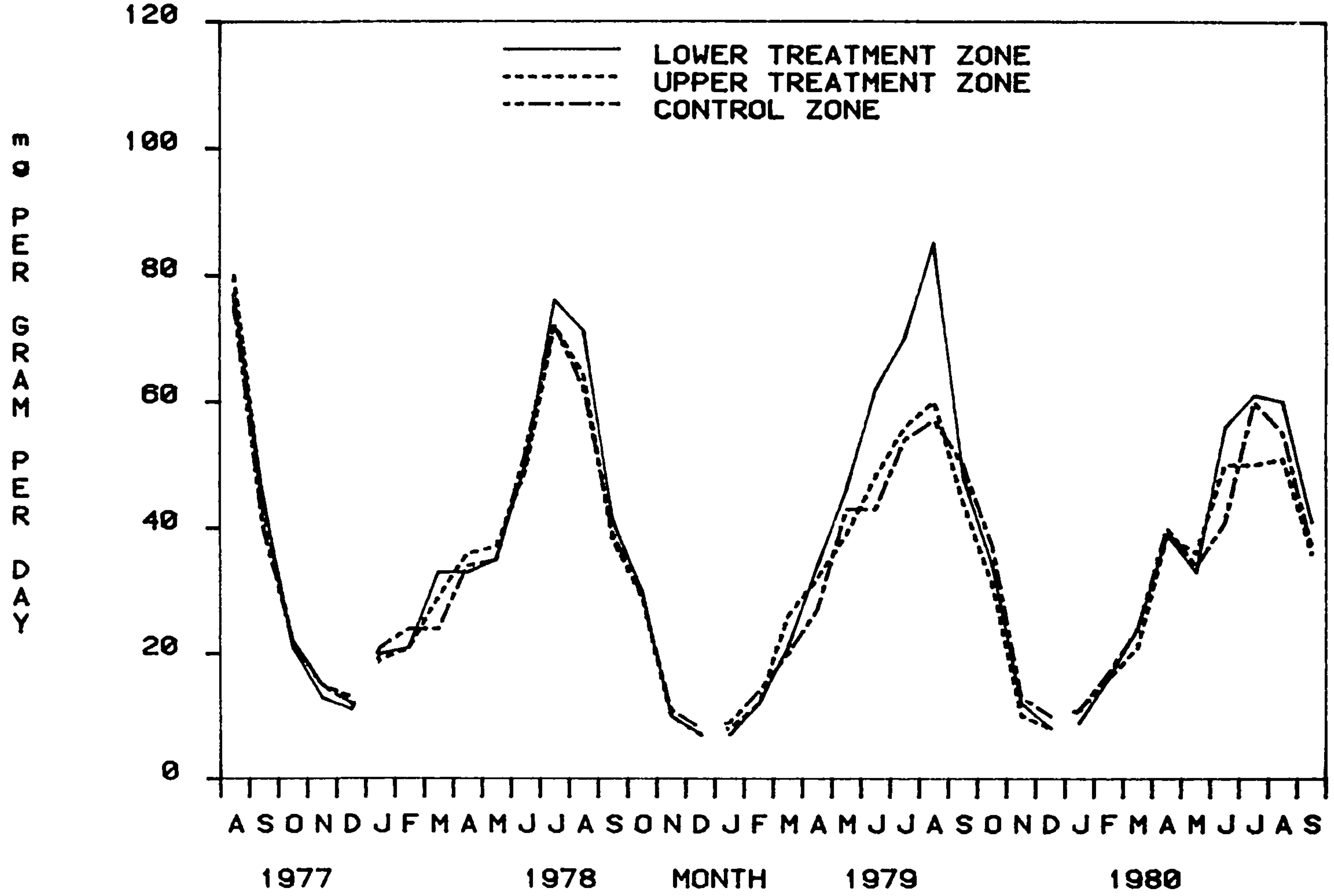

Figure 18 Mean daily consumption rate (mgg^{-1}d^{-1}) of age I cutthroat trout for treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1977-1980) streamside timber removal.

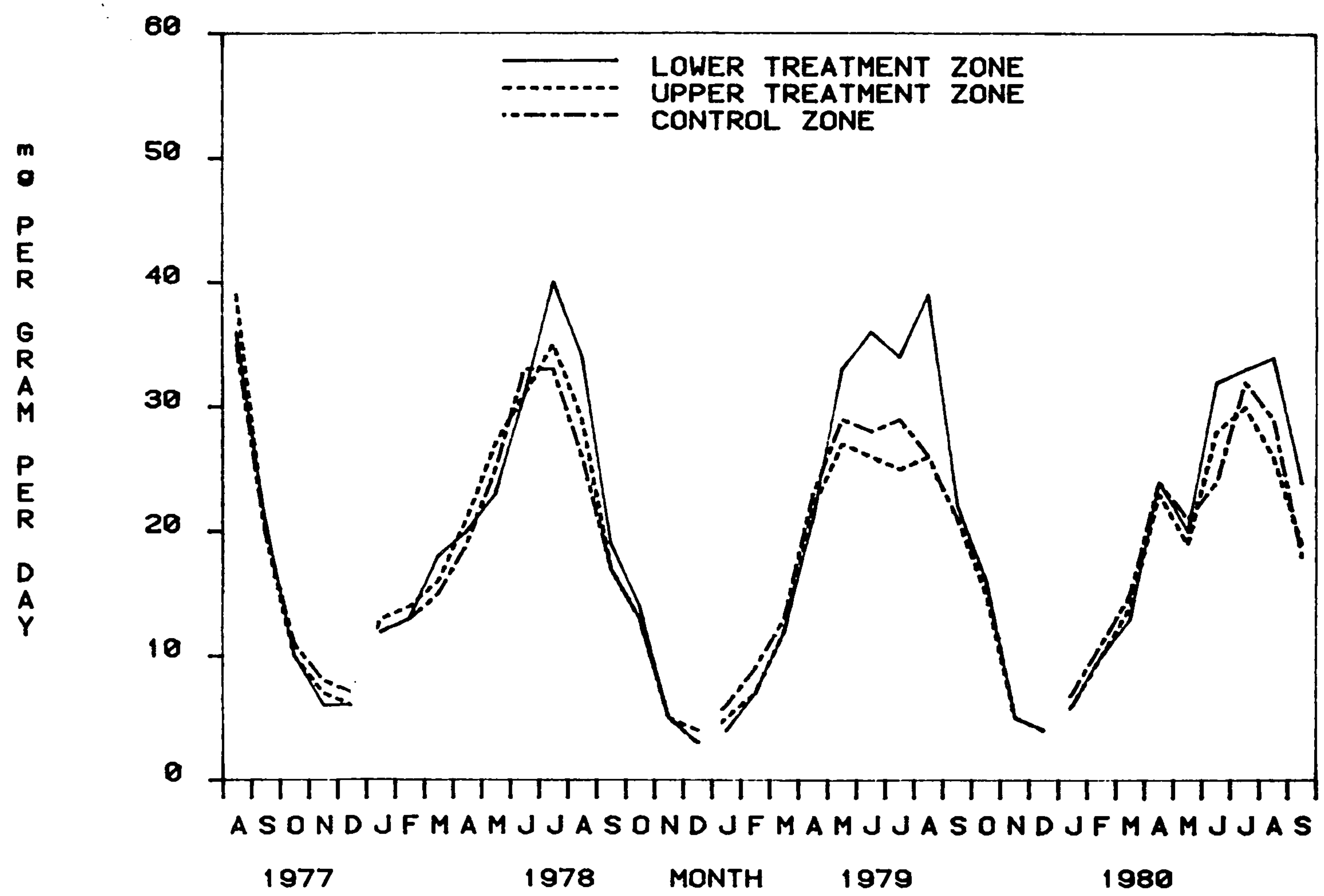

Figure 19 Mean daily consumption rate ($mgg^{-1}d^{-1}$) of age II cutthroat trout for treatment (sections 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

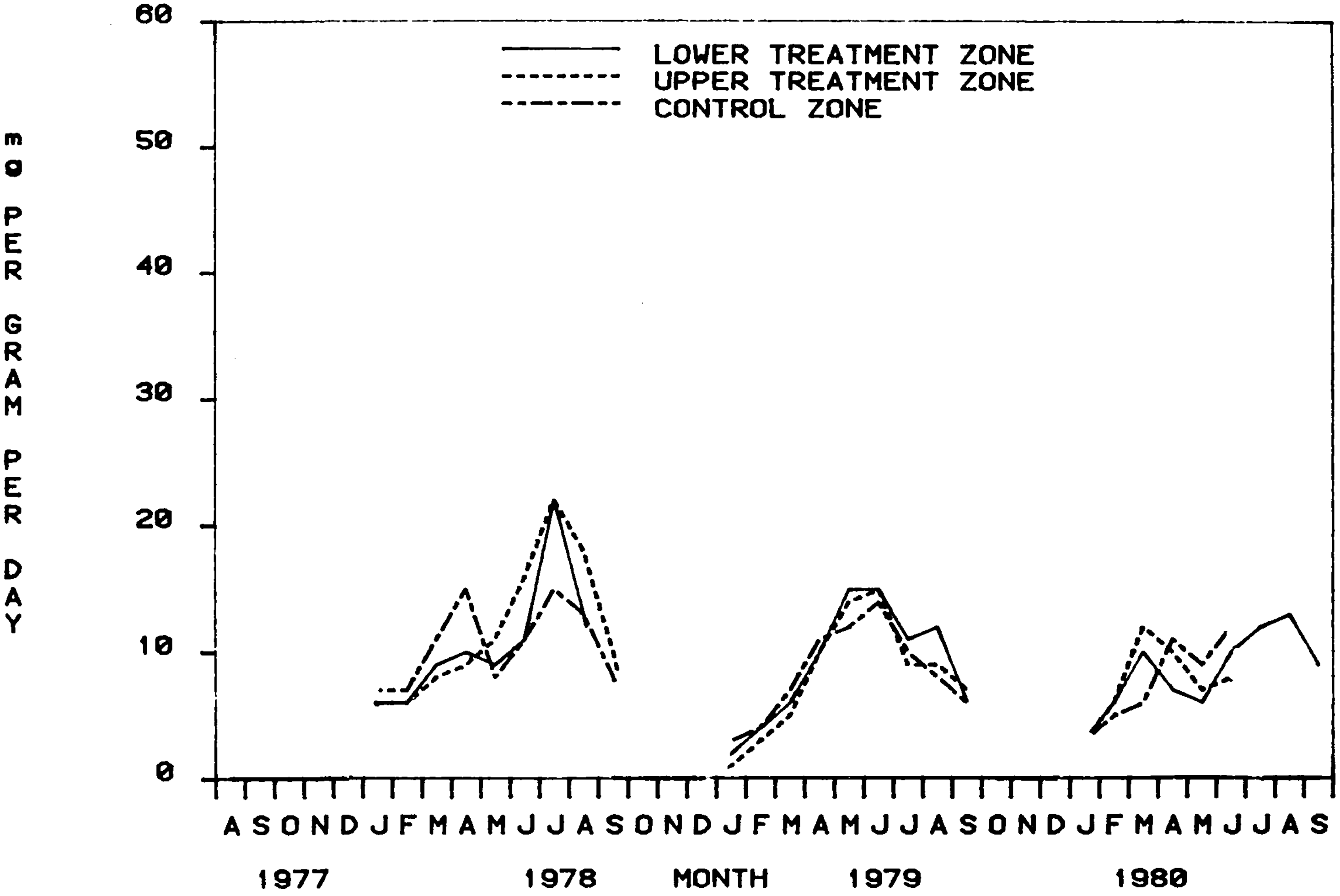

Figure 20 - Mean daily consumption rate ($mgg^{-1}d^{-1}$) of age III cutthroat trout for treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

for age I cutthroat and indistinguishable for older, age III fish (Fig. 18). This response may be due in part to the inverse relationship between weight and growth, and the similarity of mean weight of age III fish among study zones (the latter is discussed under growth). Comparisons among years indicate that consumption rate for ages 0, I, and II fish was relatively greater in the lower treatment zone during spring and summer after treatment than during the pre-treatment period. But, consumption rate was not affected by the treatment in the upper treatment zone.

Treatment effects indicate temperature and food availability were the primary factors regulating food consumption, thus the variation in response of these factors to treatment may explain the differences in consumption rate. A comparison of the trends in food supply (Figs. 7 and 16) and temperature (Fig. 4) with trends in consumption rate results indicates that temperature is the most likely factor controlling consumption rate. The greater temperature response in the lower treatment zone corresponds to the greater response in consumption rate. Also, the lower average temperature during 1980 compared to 1979 (Appendix Table 13) corresponds to the smaller response of consumption rate observed in 1980 (Figs. 17-19).

FOOD HABITS

Prey Source

The diet of cutthroat trout in Bear Creek was primarily composed of aquatic invertebrates (Table 5). The relative peak in abundance of aquatic organisms in the diet corresponds with the seasonal peak in abundance of aquatic insects (Fig. 12) for all time periods except April-May for age I and II trout, and late August for age 0 and I

Table 5

Numeric and gravimetric composition of aquatic and terrestrial organisms in the diet of cutthroat trout in Bear Creek during 1978. Terrestrial includes all organisms that spend their larval or nymph stage outside of the stream.

			Numeric		Gravimetric	
Age Group	Date	N	Terrestrial (Percent)	Aquatic (Percent)	Terrestrial (Percent)	Aquatic (Percent)
0	7-6-78	7	3	97	1	99
	8-2-78	12	6	94	24	76
	8-30-78	11	21	79	87	13
	9-29-78	13	10	90	8	92
	11-11-78	12	12	88	4	96
	Mean		10	90	25	75
I	4-28-78	5	25	75	47 a/	53
	5-23-78	15	22	78	7	93
	7-6-78	14	4	96	13	87
	8-2-78	11	4	96	26	74
	8-30-78	16	17	83	41	59
	9-29-78	11	8	92	39 b/	61
	11-11-78	11	13	87	32 c/	68
	Mean		13	87	29	71
II	4-28-78	15	10	90	14	86
	5-23-78	9	16	84	8	92
	7-6-78	2	3	97	1	99
	Mean		10	90	7	93

---

a/ Seventeen percent of weight was contributed by a few semi-aquatic beetles in the stomachs of two fish.

b/ Seven percent of weight was contributed by one Stylommatophora (slug).

c/ Twenty percent of weight was contributed by Stylommatophora.

trout. During these periods, terrestrial organisms were utilized to a large degree and provided a significant proportion of the consumed biomass.

Size Composition

The size composition of prey consumed by cutthroat trout varied according to fish size and time of year (Table 6). Older and larger trout consumed larger prey than younger trout. However, differences in prey size composition among different trout age groups were minimal with prey organisms $\leq$ 6 mm representing >85 percent of the diet for all fish. Seasonal differences in prey size composition varied from a peak occurrence of small organisms in the diet during July and August, to minimal occurrence during autumn.

Trout of all age groups exhibited preference in the size of organisms consumed. The proportion of each prey size in the diet relative to prey size groups available in benthos and insect fallout is depicted by the electivity index of Ivlev (1962) (Table 7). Prey preferences based on the availability of benthic organisms indicate that trout have a significant preference for larger prey organisms. Their greatest preference was for organisms in the 9-12 mm size group. Also, older/larger trout tended to have a greater preference for larger organisms than younger trout. On the other hand, prey preferences based on the availability of insect fallout indicate that trout did not have significant size preference or avoidance. Thus, trout consumed different size groups of terrestrial organisms in about the same proportion as their occurrence in the environment.

POPULATION DYNAMICS

The abundance of cutthroat trout in Bear Creek fluctuated on an annual basis as a result of temporal and spatial variations in spawning. The

Table 6

Relative size composition of prey organisms in the stomachs of cutthroat trout in Bear Creek during 1978

Age Group	Date	Length Group (mm) (in percent)				
		≤3	>3 to ≤6	>6 to ≤9	>9 to ≤12	>12
0	7-6-78	65.0	18.2	10.3	2.4	4.0
	8-2-78	91.5	8.0	0.5	-	-
	8-30-78	65.5	26.3	4.1	2.9	1.2
	9-29-78	54.1	38.9	6.2	0	0.8
	11-11-78	52.6	40.2	2.9	1.8	2.5
	Mean	65.7	26.3	4.8	1.4	1.7
I	4-28-78	57.8	31.4	9.4	0	1.4
	5-23-78	49.3	36.7	10.5	2.6	0.8
	7-6-78	59.3	31.8	4.2	1.5	2.4
	8-2-78	73.0	21.0	3.6	0.8	1.6
	8-30-78	50.7	41.5	4.1	1.0	2.6
	9-29-78	35.7	45.5	13.5	2.3	3.0
	11-11-78	26.3	54.2	10.2	2.6	6.7
	Mean	50.3	37.4	7.9	1.5	2.6
II	4-28-78	32.6	45.6	13.4	5.1	3.2
	5-23-78	33.6	51.5	10.1	1.6	3.1
	7-6-78	66.7	30.0	3.3	-	-
	Mean	44.3	42.4	8.9	2.2	2.1

Table 7

Size specific utilitization E(I)[a] of benthos and insect fallout prey organisms by cutthroat trout in Bear Creek during 1978

Age Group	Sample Period	Electivity Index by Length Group (mm)				
		≤3	>3 to ≤6	>6 to ≤9	>9 to ≤12	>12
		Benthos				
Age 0	July-Oct	-0.3	2.1	3.0	6.0	4.7
Age I	Apr-Oct	-0.4	1.2	3.6	6.5	5.5
Age II	Apr-July	-0.4	0.8	3.2	10.0	4.2
		Insect Fallout				
Age 0	July-Oct	0.4	-0.4	-0.2	-0.4	0.3
Age I	May-Oct	0.0	0.2	-0.2	-0.5	0.6
Age II	May-July	-0.2	1.3	-0.5	0.0	2.9

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[a] Based on formula for electivity index E(I) (Ivlev 1962).

number of searun cutthroat that spawned in the study area fluctuated from year to year as a result of the occurrence of low streamflow during the period of upstream migration (Martin et al. 1981). Low streamflows prevented passage of spawners over the Bear Creek waterfalls (Fig. 2) during December and January of 1976-77 and 1978-79 (Fig. 3). Consequently, the abundance of age 0 trout was significantly lower ($p<0.05$) in autumn of 1977 and 1979 compared to abundance during autumn of 1978 and 1980 (Fig. 21). Also, most searun cutthroat spawned in the lower and upper treatment zones and only one or two redds were observed in the control zone during any year. Since emergent fry tend to disperse in a downstream direction, annual variations in recruitment were larger in the treatment zones than in the control zone (Figs. 21-23 and Appendix Tables 17-19). The population of age 0 cutthroat trout in the control zone was maintained by resident spawners; thus the difference in abundance of age 0 fish among years was not significant ($p<0.05$) (Table 8). No response in density of age 0 trout to the riparian treatment could be detected because of the large variations in recruitment.

The population of age I cutthroat in Bear Creek exhibited a sharp increase in number as a result of recruitment of new individuals from upstream tributaries (Figs. 21-23). This redistribution of the age I population normally occurred in all study zones and for all year classes except 1979 in the upper treatment and control zones. An absence of recruitment to the age I population suggests that the abundance of age I trout is dependent upon the abundance of age 0 trout during the preceding year. Consequently, the populations of age I trout produced from the 1977 and 1979 year classes may not reflect the effect of the treatment, but rather the effects of low recruitment. As a result, the analysis of population responses to the treatment is limited to comparisons of age I trout populations from the 1976 and 1978 year classes.

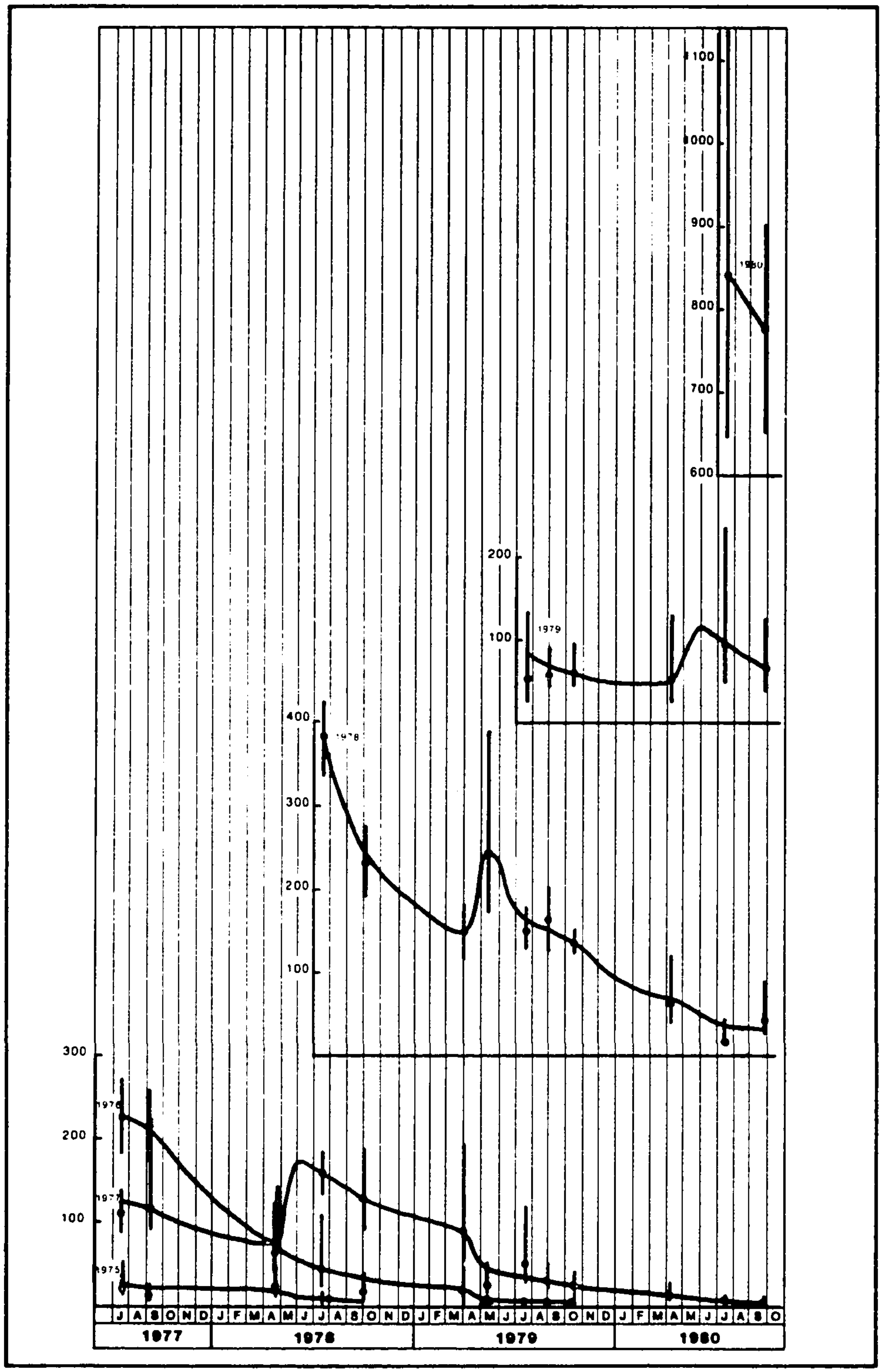

Figure 21 - Cutthroat trout abundance and 95 percent confidence interval by year class in the lower treatment zone (section 0-500) of Bear Creek during 1977 - 1980.

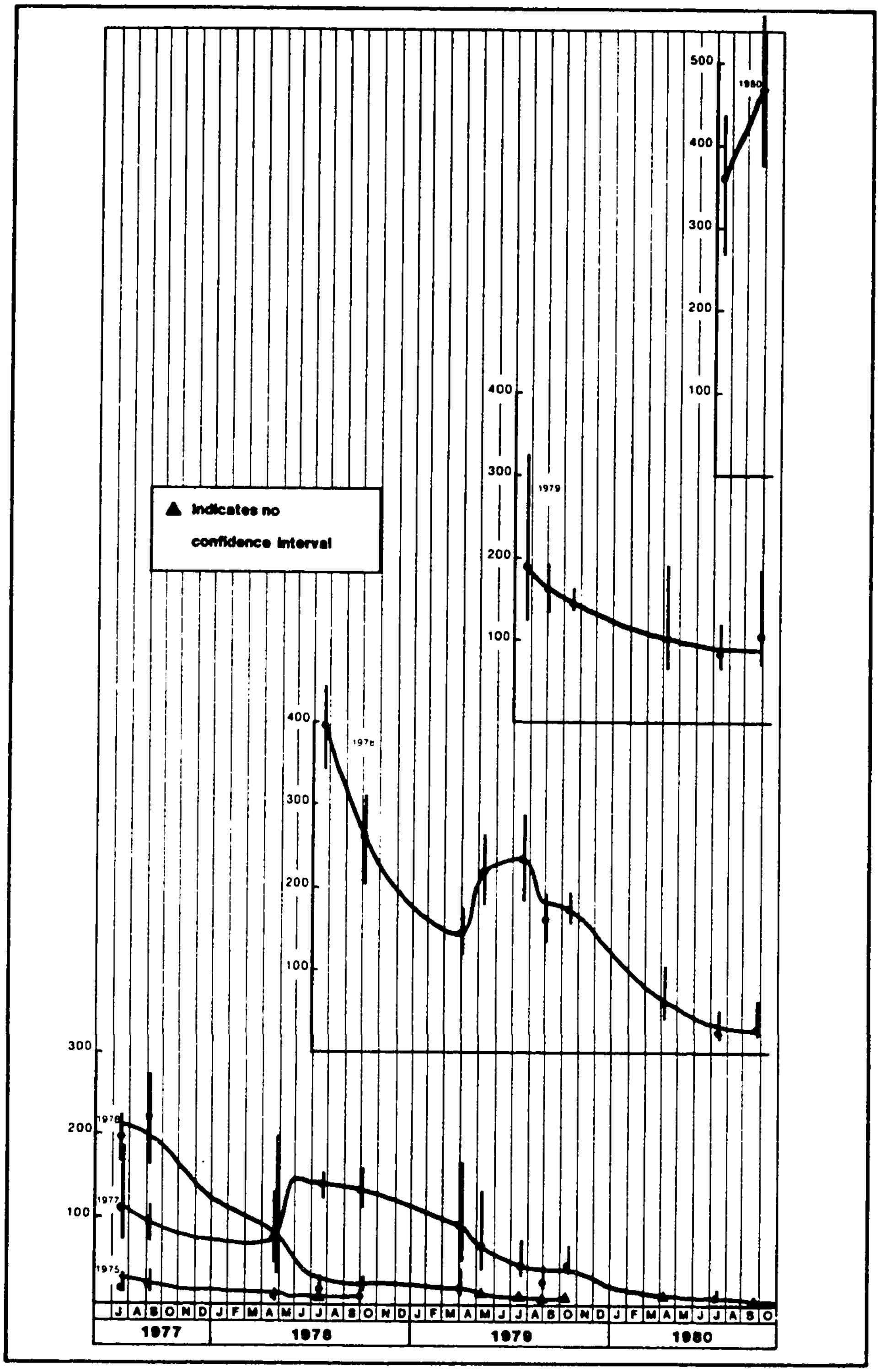

Figure 22 - Cutthroat trout abundance and 95 percent confidence interval by year class in the upper treatment zone (section 500-1000) of Bear Creek during 1977 - 1980.

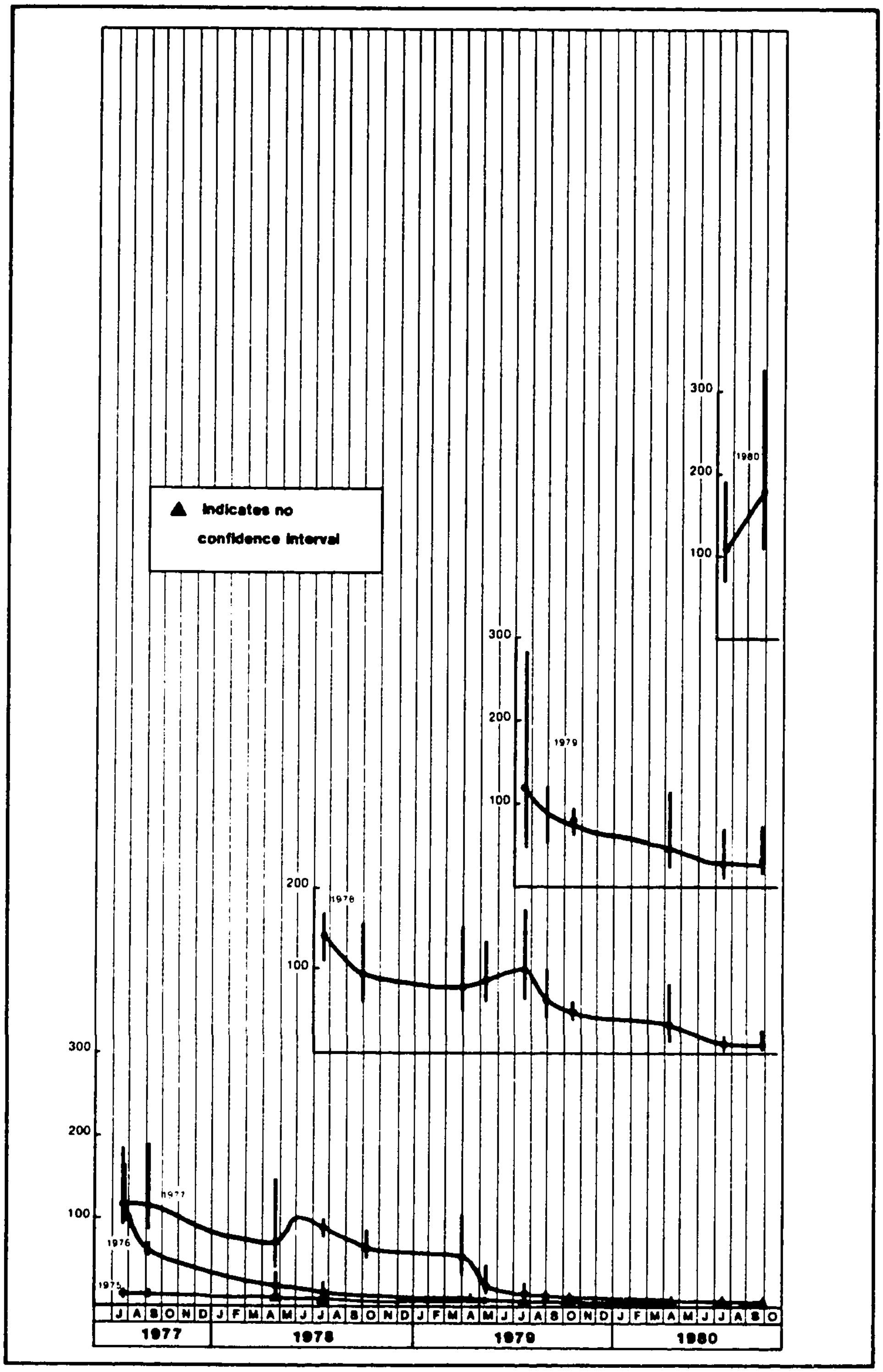

Figure 23 - Cutthroat trout abundance and 95 percent confidence interval by year class in the control zone (section 1000-1200) of Bear Creek during 1977 - 1980.

Table 8
Results of multiple comparison tests (Z) of autumn population estimates among years (1977-1980) for treatment (Sections 0-500, 500-1000) and control (Section 1000-1200) zones of Bear Creek

<table>
<tr><th>Age Group</th><th>Section</th><th></th><th colspan="4">Replication</th></tr>
<tr><td>0</td><td>0-500</td><td>(yr)[a]</td><td>79</td><td>77</td><td>78</td><td>80</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>59</td><td>136</td><td>233</td><td>775</td></tr>
<tr><td></td><td></td><td>(sim)</td><td>———</td><td>———</td><td>———</td><td>———</td></tr>
<tr><td>0</td><td>500-1000</td><td>(yr)</td><td>77</td><td>79</td><td>78</td><td>80</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>95</td><td>162</td><td>258</td><td>469</td></tr>
<tr><td></td><td></td><td>(sim)</td><td>———</td><td>———</td><td>———</td><td>———</td></tr>
<tr><td>0</td><td>1000-1200</td><td>(yr)</td><td>79</td><td>78</td><td>77</td><td>80</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>94</td><td>76</td><td>114</td><td>179</td></tr>
<tr><td></td><td></td><td>(sim)</td><td colspan="4">————————————————————</td></tr>
<tr><td>I</td><td>0-500</td><td>(yr)</td><td>80</td><td>78</td><td>79</td><td>77</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>58</td><td>125</td><td>137</td><td>215</td></tr>
<tr><td></td><td></td><td>(sim)</td><td>———</td><td colspan="2">——————————</td><td>———</td></tr>
<tr><td>I</td><td>500-1000</td><td>(yr)</td><td>80</td><td>78</td><td>79</td><td>77</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>107</td><td>137</td><td>176</td><td>221</td></tr>
<tr><td></td><td></td><td>(sim)</td><td></td><td></td><td colspan="2">——————————</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">——————————</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">——————————</td><td></td><td></td></tr>
<tr><td>I</td><td>1000-1200</td><td>(yr)</td><td>80</td><td>79</td><td>77</td><td>78</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>33</td><td>49</td><td>60</td><td>66</td></tr>
<tr><td></td><td></td><td>(sim)</td><td colspan="2">——————————</td><td colspan="2">——————————</td></tr>
<tr><td>II</td><td>0-500</td><td>(yr)</td><td>77</td><td>78</td><td>79</td><td>80</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>11</td><td>17</td><td>27</td><td>43</td></tr>
<tr><td></td><td></td><td>(sim)</td><td></td><td></td><td colspan="2">——————————</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">——————————</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">——————————</td><td></td><td></td></tr>
<tr><td>II</td><td>500-1000</td><td>(yr)</td><td>78</td><td>77</td><td>80</td><td>79</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>13</td><td>19</td><td>32</td><td>45</td></tr>
<tr><td></td><td></td><td>(sim)</td><td></td><td></td><td colspan="2">——————————</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">——————————</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">——————————</td><td></td><td></td></tr>
<tr><td>II</td><td>1000-1200</td><td>(yr)</td><td>78</td><td>79</td><td>77</td><td>80</td></tr>
<tr><td></td><td></td><td>(pop)</td><td>5</td><td>6</td><td>8</td><td>12</td></tr>
<tr><td></td><td></td><td>(sim)</td><td>---</td><td>---</td><td>---</td><td>---[b]</td></tr>
</table>

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[a] Year/Population/Similarity.

[b] Data insufficient to perform comparison test.

The results of multiple comparisons tests among years for age I trout (Table 8) indicates that the treatment had a small effect on the population. Fish abundance was significantly lower after treatment (1979) compared to pre-treatment levels (1977) for both the lower treatment and control zones, but decreases in the upper treatment zonewere not significant. The absence of a significant change in the upper treatment zone suggests that the population exhibited a positive-but- moderate response to the treatment.

Trends in the abundance of age II trout indicate a sharp decrease in population size that occured during spring (Figs. 21-23) in response to the outmigration of searun presmolts (June 1981). The number of fish remaining after the spring migrations is assumed to represent the systems capacity to support larger (i.e., older) trout. The small number of age II trout present during autumn prohibits a statistical comparison among years for the control zone. Nevertheless, statistical comparisons for the treatment zones relative to population trends in the control zone suggests that population size increased in the upper treatment zones after treatment. Further evidence of a positive response was demonstrated by the high abundance of age II fish in 1979, which were the survivors of a small 1977 year class.

Comparisons among age III trout populations could not be performed because of the small number of fish that occupy Bear Creek. Age III or older trout were not always caught in all study zones during all sample surveys.

GROWTH

The population growth rate of cutthroat trout in Bear Creek follows a seasonal cycle of high growth during early spring, a moderate decline during mid to late summer, followed by a gradual reduction to near zero by mid-autumn (Figs. 24-26) and Appendix Tables 20-22. During winter, the growth rate remained near zero, and negative in some cases. Growth rate was inversely related to age (see Appendix Tables 23-25). Growth of age 0 trout was near 21 mg g^{-1} d^{-1} during August and was probably greater during early summer. Peak growth for age I, II, and III trout was 14.5, 10.0, and 8.6 mg $g^{-1}d^{-1}$, respectively. The response of fish growth to the treatment was tested by an ANOVA of mean fish weight measured during the autumn population census. Comparisons among study zones (Table 9) indicate that the mean weight of age 0 trout was significantly greater in the lower treatment zone during one of the two years (i.e., 1979) following streamside timber removal. Further, the mean weight of cutthroat in the lower treatment zone was significantly greater during 1979 compared to all other years (Table 10). Since growth could be a function of density dependence then the high growth observed in 1979 could be a result of low recruitment rather than an effect of treatment. But a correlation analysis of trout density at the beginning of August with the growth increment during August through September indicated a weak relationship ($r=-0.21$) and was not significant ($p>0.05$). Therefore, growth of age 0 trout was improved as a result of the treatment.

A comparison of mean weight among study zones and years for age I trout (Tables 9 and 10) indicates growth had increased in the lower treatment zone (1979 and 1980) and in the upper treatment zone (1980) following treatment. Correlation analysis of trout density at the beginning of the year with the yearly growth increment was not significant ($r=-0.39$, $p>0.05$). Tests on differences in mean weight for older trout (i.e., age groups II and III) were not significant. Therefore, growth of age II and age III trout was not affected by the treatment.

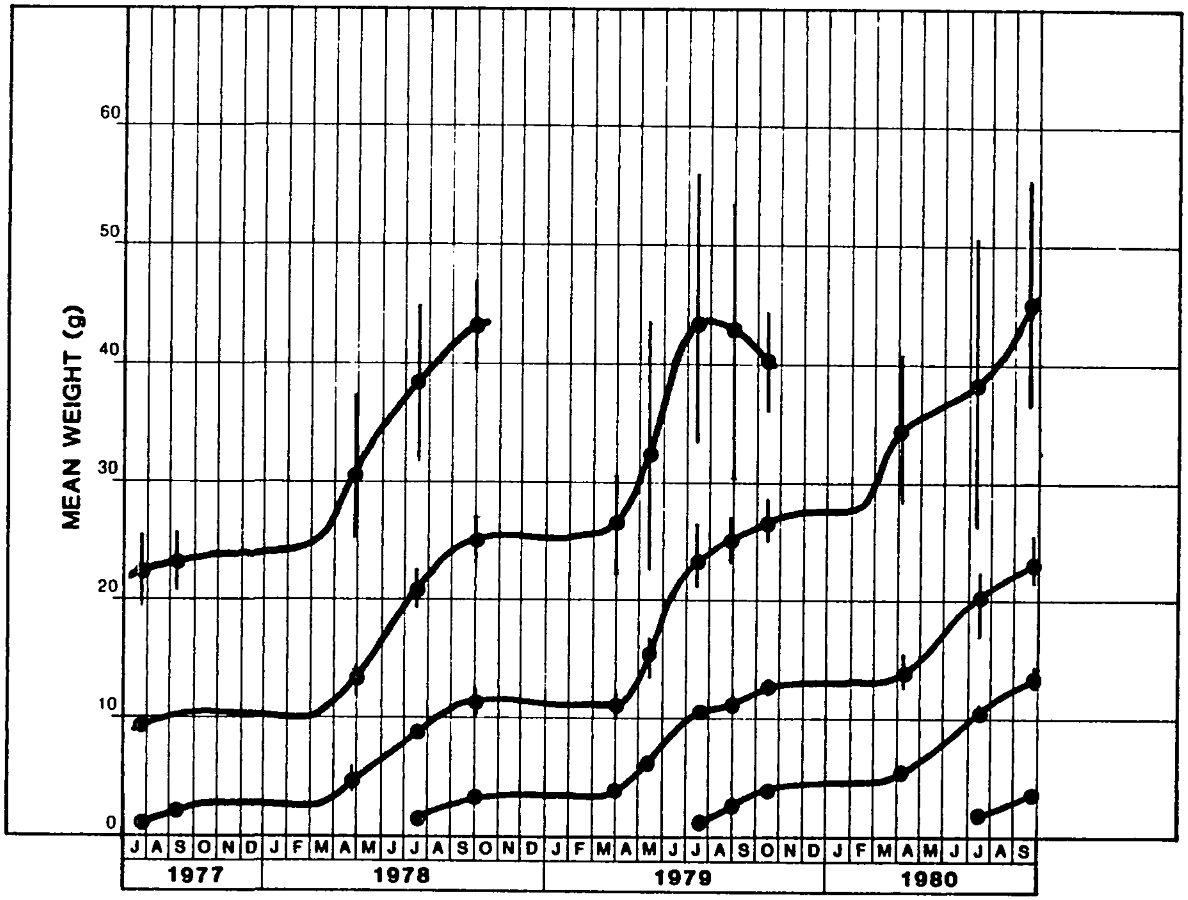

Figure 24 - Growth, mean weight, and 95 percent confidence interval of cutthroat trout, by year class, in the lower treatment zone (section 0-500) of Bear Creek during 1977-1980.

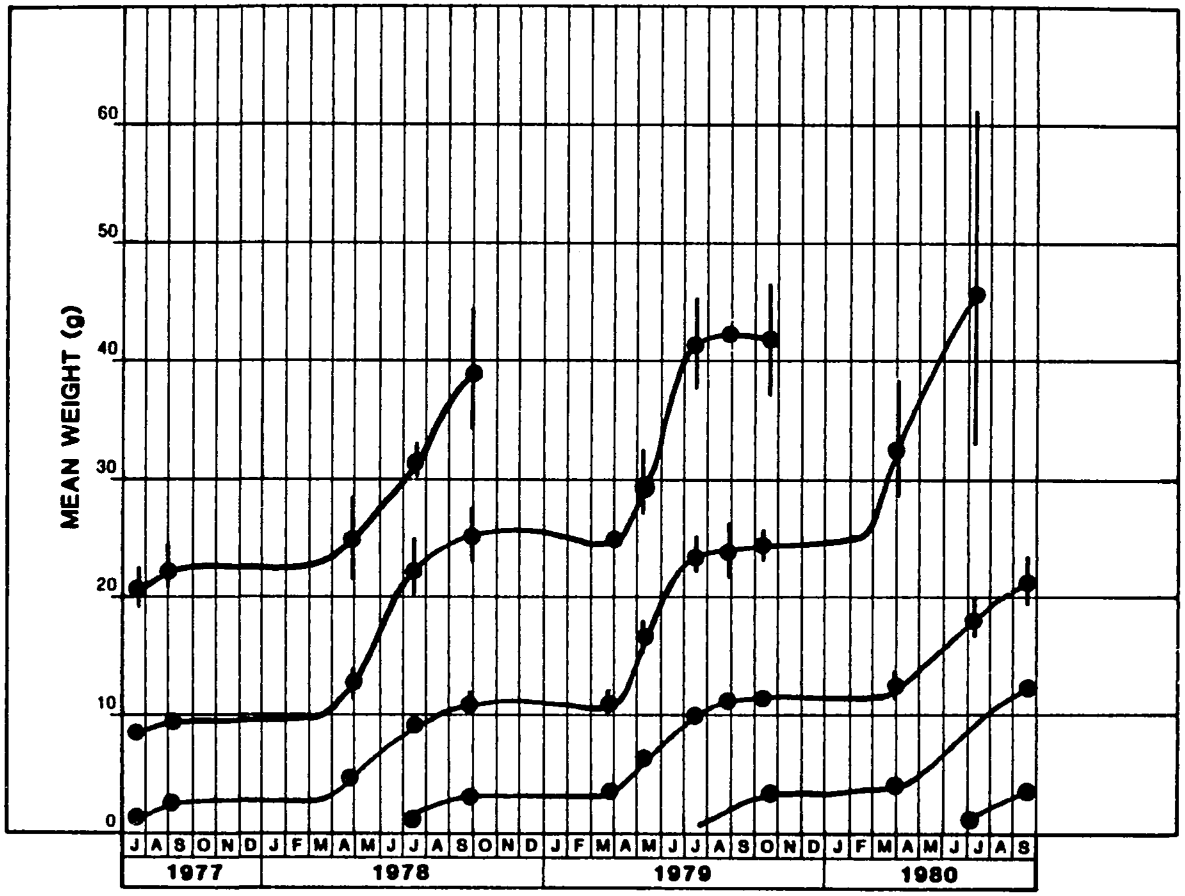

Figure 25 - Growth, mean weight, and 95 percent confidence interval of cutthroat trout, by year class, in the upper treatment zone (section 500-1000) of Bear Creek during 1977-1980.

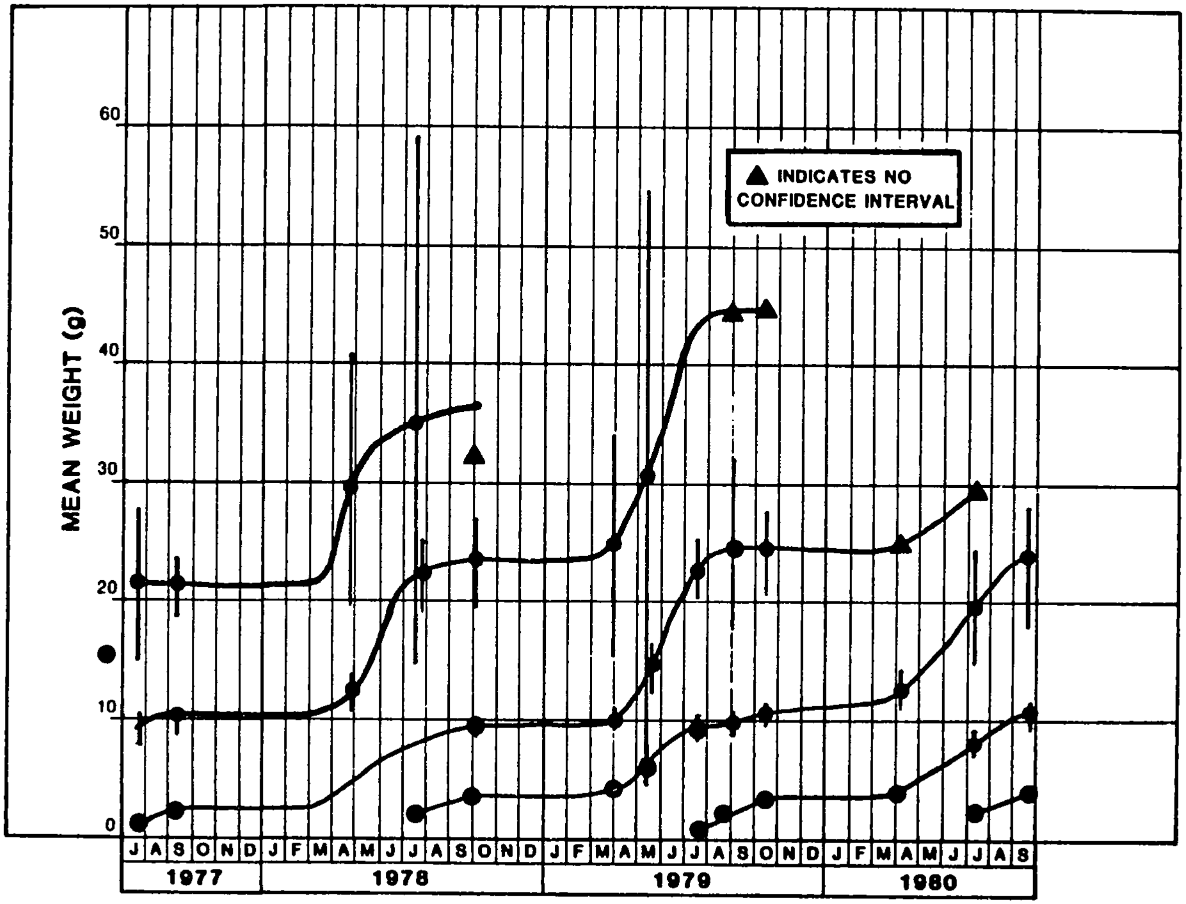

Figure 26 - Growth, mean weight, and 95 percent confidence interval of cutthroat trout, by year class, in the control (section 1000-1200) zone of Bear Creek during 1977-1980.

Table 9
Results of ANOVA and multiple comparison tests on mean weight of cutthroat trout tested among years for treatment (Sections 0-500, 500-1000) and control (Section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal

Age Group	Year	ANOVA F. Prob.		Replication		
0	1977	.059	(sec)[a/]	0-500	1000-1200	500-1000
			(wt)	2.28	2.33	2.56
			(sim)	————	————	————
	1978	.163	(sec)	500-1000	0-500	1000-1200
			(wt)	3.17	3.34	3.42
			(sim)	————	————	————
	1979	.000	(sec)	1000-1200	500-1000	0-500
			(wt)	3.11	3.34	3.98
			(sim)	————	————	————
	1980	.071	(sec)	0-500	500-1000	1000-1200
			(wt)	3.55	3.74	3.83
			(sim)	————	————	————
I	1977	.039	(sec)	500-1000	1000-1200	0-500
			(wt)	9.32	9.95	10.21
			(sim)	————	———— ————	 ————
	1978	.003	(sec)	1000-1200	500-1000	0-500
			(wt)	9.48	11.11	11.61
			(sim)	————	————	————
	1979	.000	(sec)	1000-1200	500-1000	0-500
			(wt)	10.62	11.38	12.70
			(sim)	————	————	————
	1980	.001	(sec)	1000-1200	500-1000	0-500
			(wt)	10.77	12.49	13.27
			(sim)	————	————	————

II No significant difference (F>0.05) among sections for all years.

III No significant difference (F>0.05) among sections for all years.

---

a/ Section/mean weight(g)/similarity.

Table 10
Results of ANOVA and multiple comparison tests on mean weight of cutthroat trout tested among years for treatment (0-500, 500-1000) and control (Sections 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal

<table>
<tr><th>Age Group</th><th>Section</th><th>ANOVA
F. Prob.</th><th></th><th colspan="4">Replication</th></tr>
<tr><td>0</td><td>0-500</td><td>.000</td><td>(yr)[a/]</td><td>77</td><td>78</td><td>80</td><td>79</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>2.28</td><td>3.33</td><td>3.54</td><td>3.97</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td>———</td><td colspan="2">——————</td><td>———</td></tr>
<tr><td>0</td><td>500-1000</td><td>.000</td><td>(yr)</td><td>77</td><td>78</td><td>79</td><td>80</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>2.56</td><td>3.17</td><td>3.33</td><td>3.74</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td>———</td><td colspan="2">——————</td><td>———</td></tr>
<tr><td>0</td><td>1000-1200</td><td>.000</td><td>(yr)</td><td>77</td><td>79</td><td>78</td><td>80</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>2.32</td><td>3.10</td><td>3.42</td><td>3.83</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td>———</td><td colspan="2">——————</td><td>———</td></tr>
<tr><td>I</td><td>0-500</td><td>.000</td><td>(yr)</td><td>77</td><td>78</td><td>79</td><td>80</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>10.21</td><td>11.61</td><td>12.70</td><td>13.27</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td>———</td><td>———</td><td colspan="2">——————</td></tr>
<tr><td>I</td><td>500-1000</td><td>.000</td><td>(yr)</td><td>77</td><td>78</td><td>79</td><td>80</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>9.31</td><td>11.11</td><td>11.38</td><td>12.49</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td>———</td><td colspan="2">——————</td><td>———</td></tr>
<tr><td>I</td><td>1000-1200</td><td>.168</td><td>(yr)</td><td>78</td><td>77</td><td>79</td><td>80</td></tr>
<tr><td></td><td></td><td></td><td>(wt)</td><td>9.48</td><td>9.94</td><td>10.62</td><td>10.77</td></tr>
<tr><td></td><td></td><td></td><td>(sim)</td><td colspan="4">————————————</td></tr>
</table>

II No significant difference (F>0.05) among sections for all years.

III No significant difference (F>0.05) among sections for all years.

[a/] Year/Mean/Weight(g)/Similarity. Lines indicate similarity among sections.

PRODUCTION

Figures 27-29 (Appendix Tables 26-28) show the seasonal trends in trout production which were computed from population (Figs. 21-23) and growth (Figs. 24-26) data. Monthly production for age III trout were not plotted because of small differences among study zones and contribution of production of <5 percent to the total population. A summary of total production for each section and age group are shown in Table 10.

Comparisons of production among study zones for each year indicate production for all age groups combined increased after streamside timber removal. During 1977 and 1978, production for each age group of cutthroat trout was different among each study zone (Figs. 27-29), but production for all age groups combined differed by no more than 21 percent relative to production in the control zone (Table 11). Following treatment, total production in the upper treatment zone during 1979 was 33 percent greater than production in the control zone. This increase was due to increased production of ages I and II trout (Figs. 28 and 29). Similarly, total production during 1980 was 69 percent and 54 percent greater in the lower and upper treatment zones, respectively, than the control zone. This large increase in production was primarily a result of increases in production of ages 0 and I trout (Figs. 27 and 28).

Changes in production after treatment were more a result of changes in trout density than changes in growth. Correlation analysis of production versus trout density at the beginning of the year identified a significant correlation with production for all age groups of trout (Table 12). On the other hand, correlations between production and the yearly growth increment were not significant except for age III trout. Since the density of age 0 trout was found to be closely associated with recruitment, the high production of age 0 trout observed in 1980 was unlikely a result of the treatment, but rather a result of high

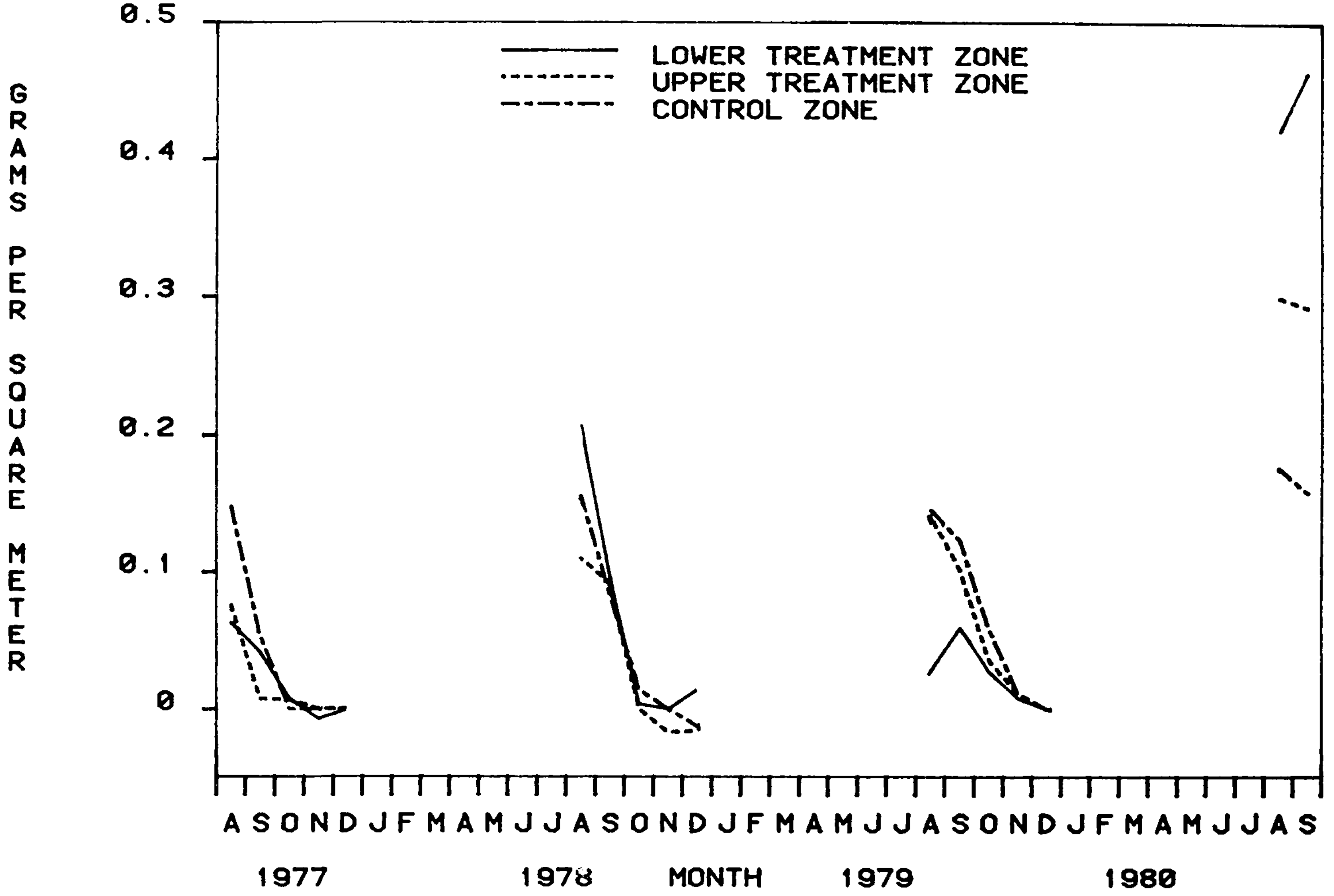

Figure 27 - Monthly production of age 0 cutthroat trout in treatment (section 0-500, 500-1000) and control (1000-1200) zones of Bear Creek, before (1977 - 1978) and after (1979 - 1980) streamside timber removal.

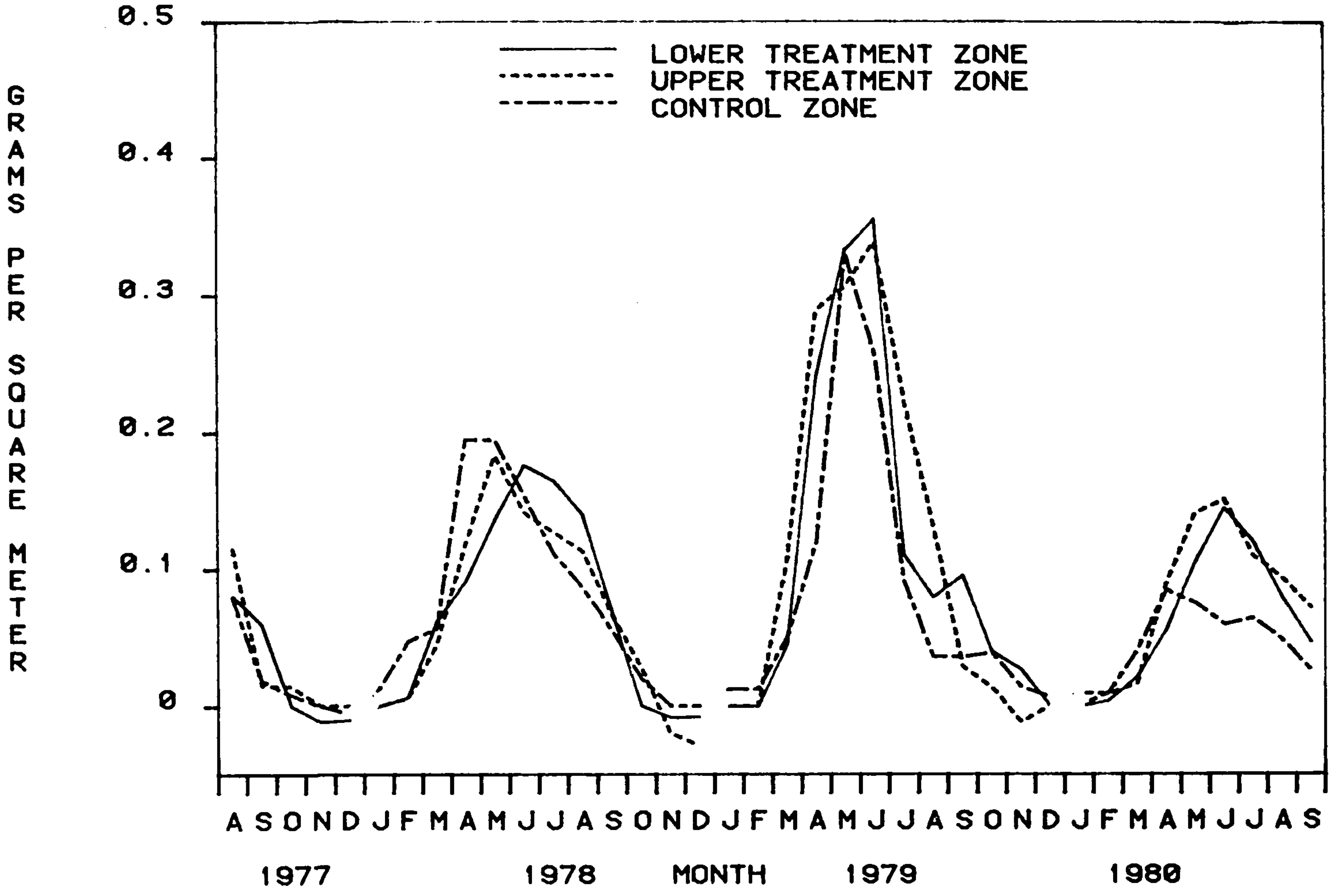

Figure 28 - Monthly production of age I cutthroat trout in treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

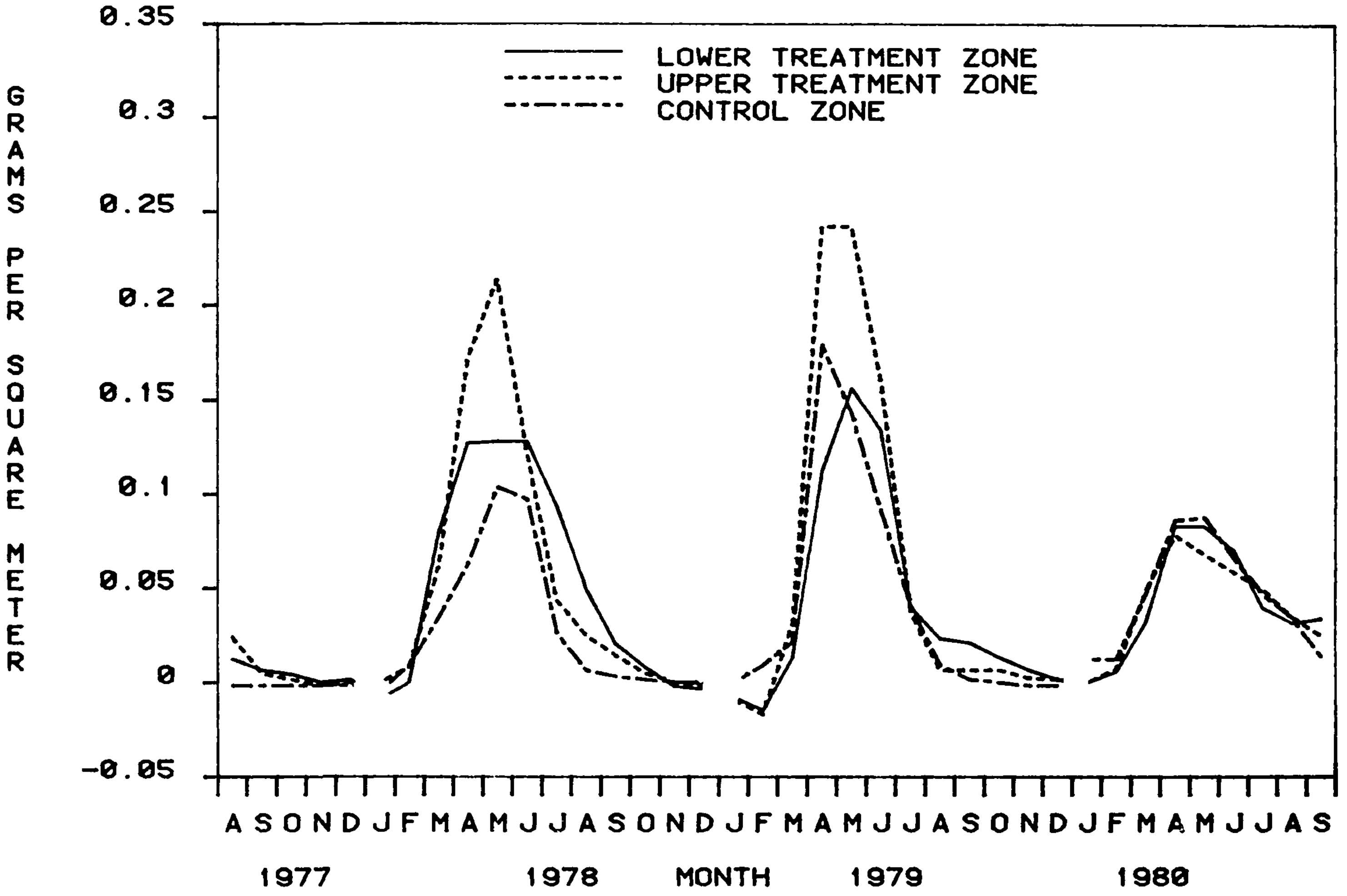

Figure 29 - Monthly production of age II cutthroat trout in treatment (section 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal.

Table 11

Production per unit stream area (gm^{-2}, wet wt.) of cutthroat trout in treatment (sections 0-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-1978) and after (1979-1980) streamside timber removal

Period	Age Group	Section				
		0-500 (gm^{-2})		500-1000 (gm^{-2})		1000-1200 (gm^{-2})
Aug 77-Dec 77	0	.104		.090		.201
	I	.117		.144		.099
	II	.025		.029		-.008
	III	---		---		---
	All	.246	-16%[a]	.263	-10%	.292
Jan 78-Dec 78	0	.352		.169		.240
	I	.826		.772		.931
	II	.619		.663		.340
	III	.180		.084		.127
	All	1.977	+21%	1.688	+3%	1.638
Jan 79-Dec 79	0	.122		.289		.337
	I	1.324		1.426		1.005
	II	.498		.709		.492
	III	.131		.115		.075
	All	2.075	+9%	2.539	+33%	1.909
Jan 80-Sep 80	0	.883		.593		.335
	I	.577		.692		.409
	II	.379		.369		.408
	III	.124		.134		.009
	All	1.963	+69%	1.788	+54%	1.161

---

[a] Percentage difference relative to production in control zone.

Table 12

Correlation analysis of production versus trout density and growth

Age Group	Parameters Tested	Correlation Coefficient (r)	Significance of (r)
0	Pm^{-2} vs Nm^{-2} a/	0.89	0.000
I	Pm^{-2} vs Nm^{-2}	0.71	0.032
II	Pm^{-2} vs Nm^{-2}	0.70	0.035
III	Pm^{-2} vs Nm^{-2}	0.69	0.038
0	Pm^{-2} vs G b/	0.15	0.638
I	Pm^{-2} vs G b/	0.27	0.481
II	Pm^{-2} vs G b/	0.63	0.068
III	Pm^{-2} vs G b/	0.70	0.034

---

a/ Density at the beginning of the year for age groups I, II, III or in July for age group 0.

b/ Growth increment during period when production was computed.

recruitment. A similar correspondence between variable recruitment and production of age I trout may also exist. However, this relationship is less clear. The relatively high production of age I trout in both treatment zones during 1979 and 1980 compared to 1978 suggests a positive effect of the treatment despite variations in trout recruitment.

DISCUSSION

PRODUCTION IN RELATION TO RIPARIAN VEGETATION

The response of the trout population in Bear Creek to the riparian treatment confirms the results reported by others (e.g., Aho 1976, Murphy and Hall 1981, Murphy et al. 1981, Hawkins et al. 1983) that removal of the stream canopy stimulates production of the fish food supply, causing increases in fish production. The results of this investigation also suggest the following:

- Food supply was increased as a result of increases in both terrestrial insect fallout and aquatic insect production.
- The amount of food consumed by cutthroat trout may be associated with food availability and feeding behavior.
- Different responses of growth and density of cutthroat trout to the treatment may be associated with difference in water temperature between upper and lower treatment zones.

Support for these findings are derived from the results of this study and from knowledge gained from previous investigations. The following discussion examines these results in order to provide a better understanding of the relationship between fish production and riparian vegetation.

Changes in water temperature, food supply, and fish production observed in Bear Creek were assumed to be a direct result of canopy removal and not a response to physical alterations. The timber felling treatment, which excluded log removal and road construction, did not have an affect on fish habitat other than to reduce stream surface shading to 23 percent of pretreatment levels (Table 13). However, fish habitat in

Table 13

Percentage of stream wetted surface area with three types of fish cover in five 50m-long study sections of Bear Creek before (1978) and after (1979) streamside timber removal. (From Martin et al. 1981 and June 1981).

	Cover					
	Instream[a/]		Streamside[b/]		Overhead Shade[c/]	
Section	1978	1979	1978	1979	1978	1979
75-125 m	20	19	29	31	49	10
550-600 m	18	17	28	25	61	16
900-950 m	9	19	16	11	59	14
1000-1050 m	24	23	25	6	81	35
1125-1175 m	21	19	29	30	70	58

[a/] Submerged or partially submerged objects that reduce water velocity or provide shade in the stream (e.g., logs, boulders, and root wads).

[b/] Objects providing shade and extending over the stream at levels within 0.5 meters of the stream surface (e.g., undercut bank and understory vegetation).

[c/] Objects located greater than 0.5 meters above the stream that provide shade (e.g., trees and tall understory vegetation).

some areas of the stream were altered as a result of a windstorm which occurred during the timber removal treatment. Several groups of trees blew down in the treatment zone and along the downstream edge of the control zone. This blowdown reduced steam surface shading and streamside cover in the lower 50 meters of the control zone (i.e., Section 1000-1050), and increased instream cover in Section 900-950 m (Table 13). Blowdown also caused small changes in channel morphology, but the area affected was limited to the immediate site where trees fell into the stream. Therefore, the windstorm was assumed to have a minimal affect on the overall quantity and quality of habitat in Bear Creek.

Canopy Removal and the Food Supply

Canopy removal caused an increase in food supply as a result of an increase in production of aquatic insects. This conclusion is based on the following information. Biomass of benthic macroinvertebrates was significantly greater in the upper treatment zone following treatment (Table 4). The percentage of adult aquatic insects in the insect follout traps also increased in both treatment zones following treatment (Figure 8). Since the abundance of adult aquatic insects is indicative of aquatic production, these results support the benthos results and suggest production also increased in the lower treatment zone. The latter response also agrees with White's (1981) finding that canopy removal caused a significant increase in the number of chironomids emerging in the lower treatment zone (i.e., Station 200). Since chironomids represent a significant portion of the benthic community, a change in the abundance of chironomids is assumed to reflect a change in the total abundance of aquatic insects as well. Also, White used different methods of sampling and sampled at different locations within each study zone. Thus his results provide further evidence that the low benthic biomass measured at Station 85 following treatment was not representative of the lower treatment zone.

The relative increase in biomass of insect fallout following treatment suggests that canopy removal and the associated clearcut caused this response (Table 3). Change in insect fallout may be associated with physical and biological conditions within the riparian complex. The streamside timber removal treatment destroyed all habitat associated with the upper canopy layer and disrupted much of the understory community, except that immediately adjacent to the stream. It was expected that terrestrial insect populations would have decreased for several years until a herbaceous understory was established in the clearcut area. Then insect populations, and insect fallout, would have increased in response to more habitat and an improved food base. However, the response observed at Bear Creek clearly demonstrates that other mechanisms were controlling insect fallout. Several explanations include: 1) concentrations of insect populations in the narrow strip of understory that were retained along the stream, thus increasing the density of insects close to the stream; 2) a change in air movement due to clearcutting, which could have drawn by convection more insects out of the adjacent cool forest areas and increased the abundance of insects in the vicinity of the stream; or, 3) the creation of a large thermal differential between the cool air over the stream and the adjacent warm air in the clearcut area could have caused downdrafts that would have pulled down insects flying over the stream. This latter mechanism was identified as one cause for the fallout of terrestrial insects on lakes (Norlin 1967).

Unfortunately, data needed to investigate these suggestions were not collected and would have required studies that are beyond the scope of this thesis. Other information concerning the causes of insect fallout is limited. Nelson (1965) found the catch of terrestrial insects close to a stream in Sweden was correlated with the change in air temperature. Insect activity increases with an increase in temperature, therefore he concluded that catch was correlated with activity. A study in northern California found that a disturbance of riparian vegetation by road construction parallel to a stream resulted in a twofold increase in numbers and biomass of insect fallout (Hess 1969). Hess reported that "a more than proportionate amount of the increase occurred in those adult insects having aquatic immature stages." Thus, Hess's results may be reflecting a biological stimulation of the aquatic insect community rather than an effect on terrestrial insect fallout. Other information needed to explain the mechanism of this response is not available, but could provide a fruitful area for further research.

Food Supply, Consumption, and Feeding Habits

A comparison of the total food consumption to the total production of aquatic insects and insect fallout combine would suggest that food supply does not limit food demand (Figs. 30-32). However, presence is not synonymous with availability. Food habits studies indicated that aquatic insects contributed on the average more than 70 percent of the food biomass to the diet of cutthroat trout (Table 5). On the other hand, insect fallout was not utilized to any great extent, except during August, despite its greater potential abundance. Since benthic production does not exceed food demand, except during spring and fall, the results suggest food consumption could be limited by the production of aquatic insects during the summer.

Aquatic insects appear to be more important than terrestrial insects in the diet of coastal cutthroat trout and this food preference may be due to fish behavior. The diet of cutthroat trout from the Cowichin River, British Columbia was composed of 35 percent terrestrial food by volume during the period May to September (Idyll 1942). Lowry (1966) found aquatic insects to be most important for cutthroat trout in three Oregon streams during late winter and spring. But terrestrial insects

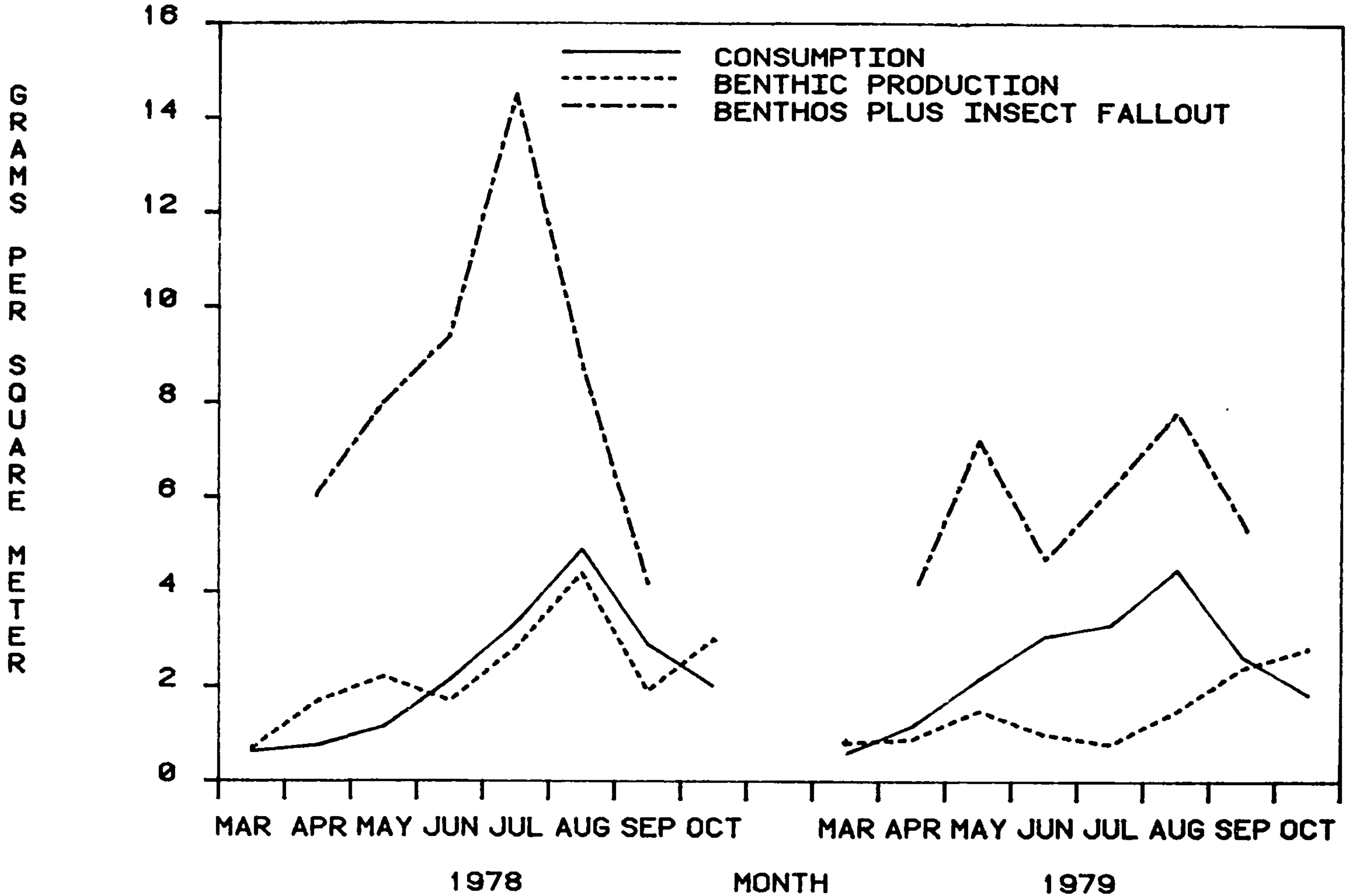

Figure 30 Cutthroat monthly food consumption (gm^{-2}), benthic production (gm^{-2}), and benthic production plus insect fallout (gm^{-2}) in the lower treatment zone (section 0-500) of Bear Creek, before (1978) and after (1979) streamside timber removal.

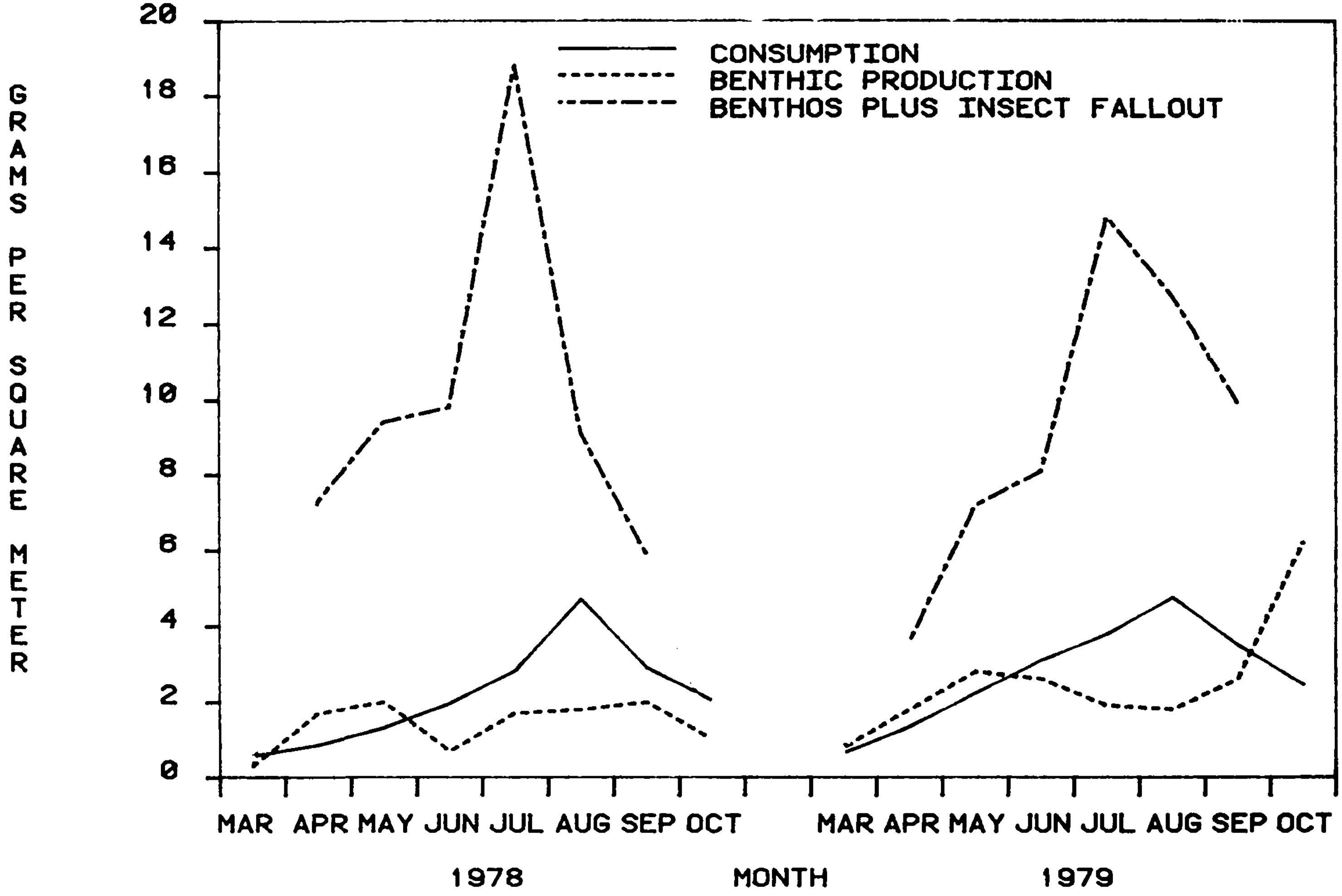

Figure 31 Cutthroat monthly food consumption (gm^{-2}), benthic production (gm^{-2}), and benthic production plus insect fallout (gm^{-2}) in the upper treatment zone (section 500-1000) of Bear Creek, before (1978) and after (1979) streamside timber removal.

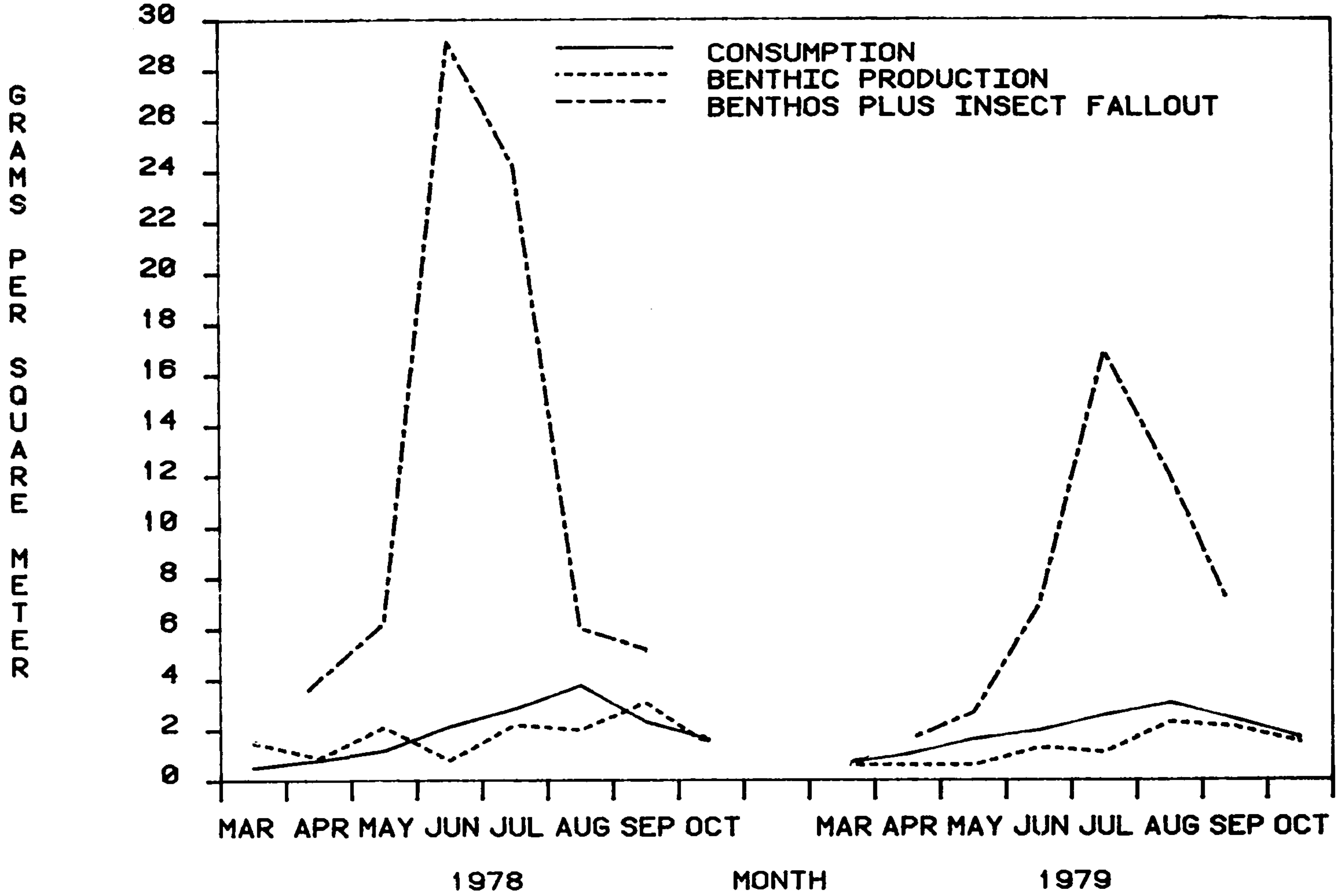

Figure 32 Cutthroat monthly food consumption (gm^{-2}), benthic production (gm^{-2}), and benthic production plus insect fallout (gm^{-2}) in the control zone (section 1000-1200) of Bear Creek, before (1978) and after (1979) streamside timber removal.

comprising up to 32 percent of the diet by late June. Lowry suggests that cutthroat trout seldom fed on terrestrial insects from the water surface because of their pool-dwelling and cover-seeking behavior. This observation agrees with the findings of June (1981) who reported the density of cutthroat trout in Bear Creek was significantly correlated with water depth (i.e., pool habitat) and the amount of cover habitat. This habitat specific behavior of cutthroat trout may limit the opportunity for trout to obtain food from insect fallout.

Only during the summer (i.e., August) low flow period when aquatic production was low, did insect fallout become more important than benthos in the trout diet. During this period, stream velocities were low and water in riffles was shallow. Hence, aquatic insect drift is probably minimal and access by fish to food producing areas may be restricted. Consequently, trout may be forced to venture out from cover and increase their utilization of terrestrial food organisms in substitution for aquatic food organisms. Since terrestrial insect fallout is abundant at this time (Figs. 30-32) the increase in fallout observed in 1979 may not be of any importance. Unfortunately food habits studies were not conducted during 1979 so this observation could not be examined.

Trout Growth and Density in Relation to Food Consumption and Temperature

Increase in food supply as a result of canopy removal caused fish production to increase as a result of changes in fish growth and population abundance. The treatment was shown to cause an increased growth of: age 0 fish in the lower treatment zone during 1979 (Fig. 33b); age I fish in the lower treatment zone during 1979, 1980, and upper treatment zone in 1980 (Fig. 34b); and, age II fish in the lower treatment zone during 1979 (Fig. 35b). On the other hand, densities of age I and II trout were increased in the upper treatment zone during 1979 (Figs. 34a and 35a). Neither density nor growth were increased in

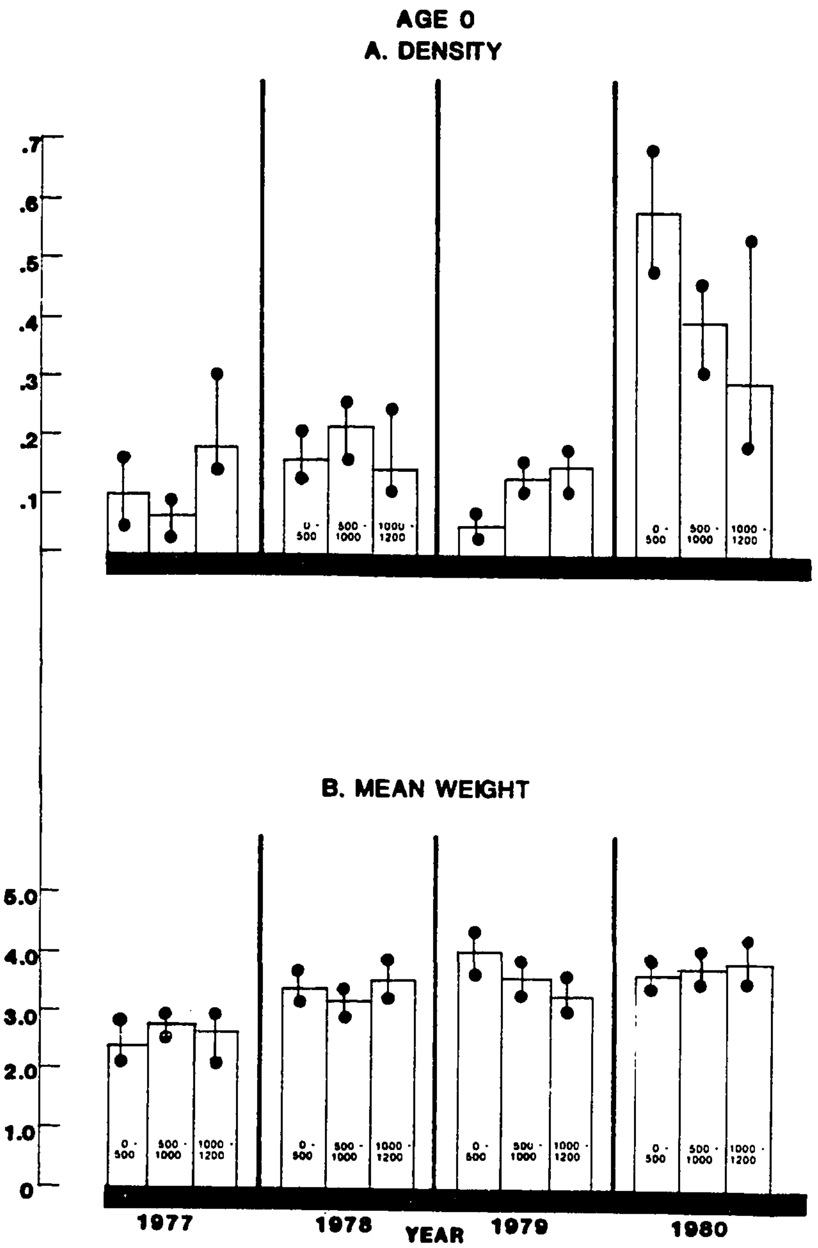

Figure 33-Density (A) and mean weight (B) with 95 percent confidence intervals (vertical bars) for age 0 cutthroat trout during the autum in treatment (section 1-500, 500-1000) and control (section 1000-1200)zones of Bear Creek, before (1977-78) and after (1979-80) streamside timber removal . . .

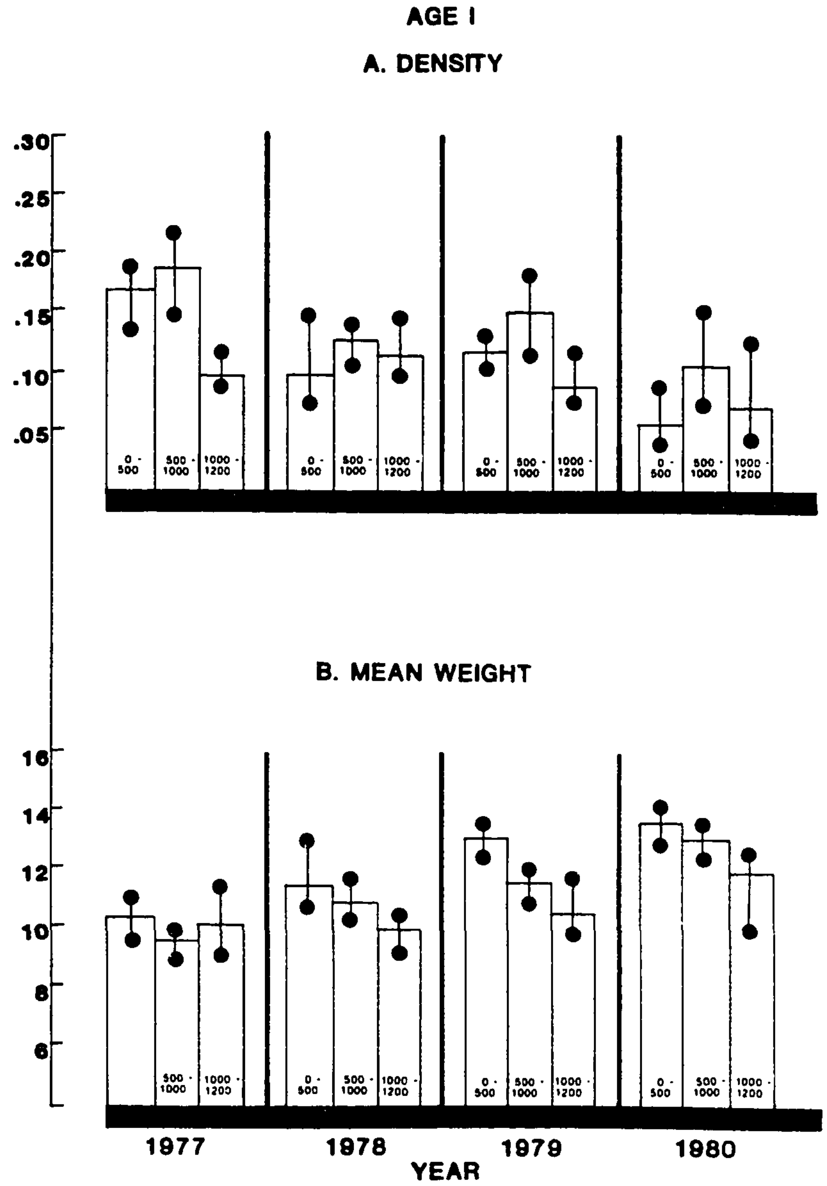

Figure 34-Density (A) and mean weight (B) with 95 percent confidence intervals (vertical bars) for age I cutthroat trout during the autum in treatment (section 1-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-78) and after (1979-80) streamside timber removal . . .

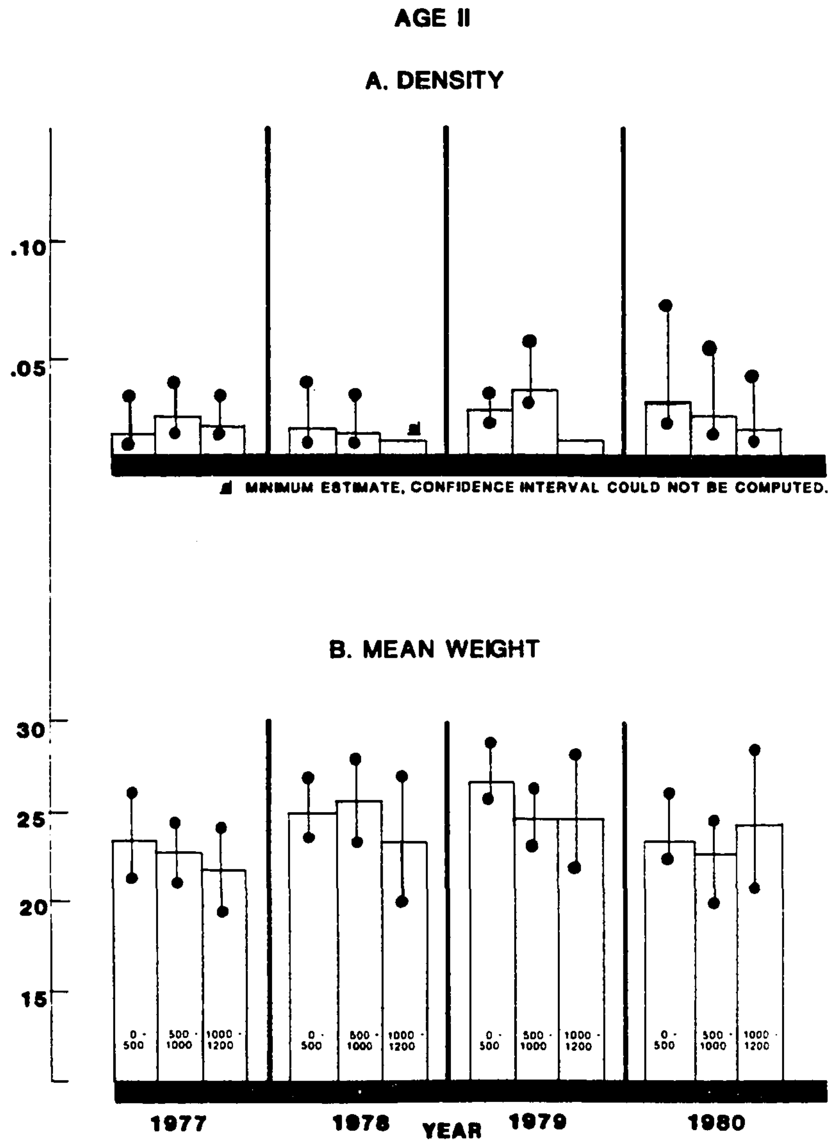

Figure 35-Density (A) and mean weight (B) with 95 percent confidence intervals (vertical bars) for age II cutthroat trout during the autum in treatment (section 1-500, 500-1000) and control (section 1000-1200) zones of Bear Creek, before (1977-78) and after (1979-80) streamside timber removal . . .

the same section in the same year. Growth increases occurred in the lower treatment zone, for the most part, and density increases only occurred in the upper treatment zone. This differential response may be associated with the differences in food consumption rate and water temperature observed in each zone.

In Bear Creek, both food supply (i.e., terrestrial and aquatic) and water temperature increased in the lower treatment zone following streamside timber removal, whereas only food supply was increased in the upper treatment zone following treatment. Since changes in growth were mostly associated with the lower treatment zone, the results suggest growth is a function of both food supply and temperature.

Food ration (i.e., food consumption) and water temperature are primary factors controlling the growth of fish (Brett 1979). However, the relationship between temperature and growth varies and is dependent upon the amount of food consumed by fish. When juvenile salmonids feed on a repletion ration, the optimum temperature for growth ranges from 15° to 17° C (Brett et al. 1969, Hokanson et al. 1977, Wurtsbaugh and Davis 1977). But, when juvenile salmonids feed on a reduced ration, the optimum temperature for growth decreases progressively with decreasing ration from about 15° to 17° C (depending upon species) at the maximum ration to about 4° to 5°C at the minimum ration for growth (Brett et al. 1969, Elliott 1975). In Bear Creek, cutthroat trout were assumed to be feeding on a reduced ration. Thus an increase in food consumption in the lower treatment zone (see Figs. 17-20) and a moderate increase in water temperature (Fig. 4) improved the physiological conditions for growth.

Evidence that ration and temperature were limiting growth is demonstrated by a comparison of the seasonal variations of consumption rate, growth rate, and gross conversion efficiency (Fig. 36). Gross conversion efficiency is an indicator of environmental suitability for

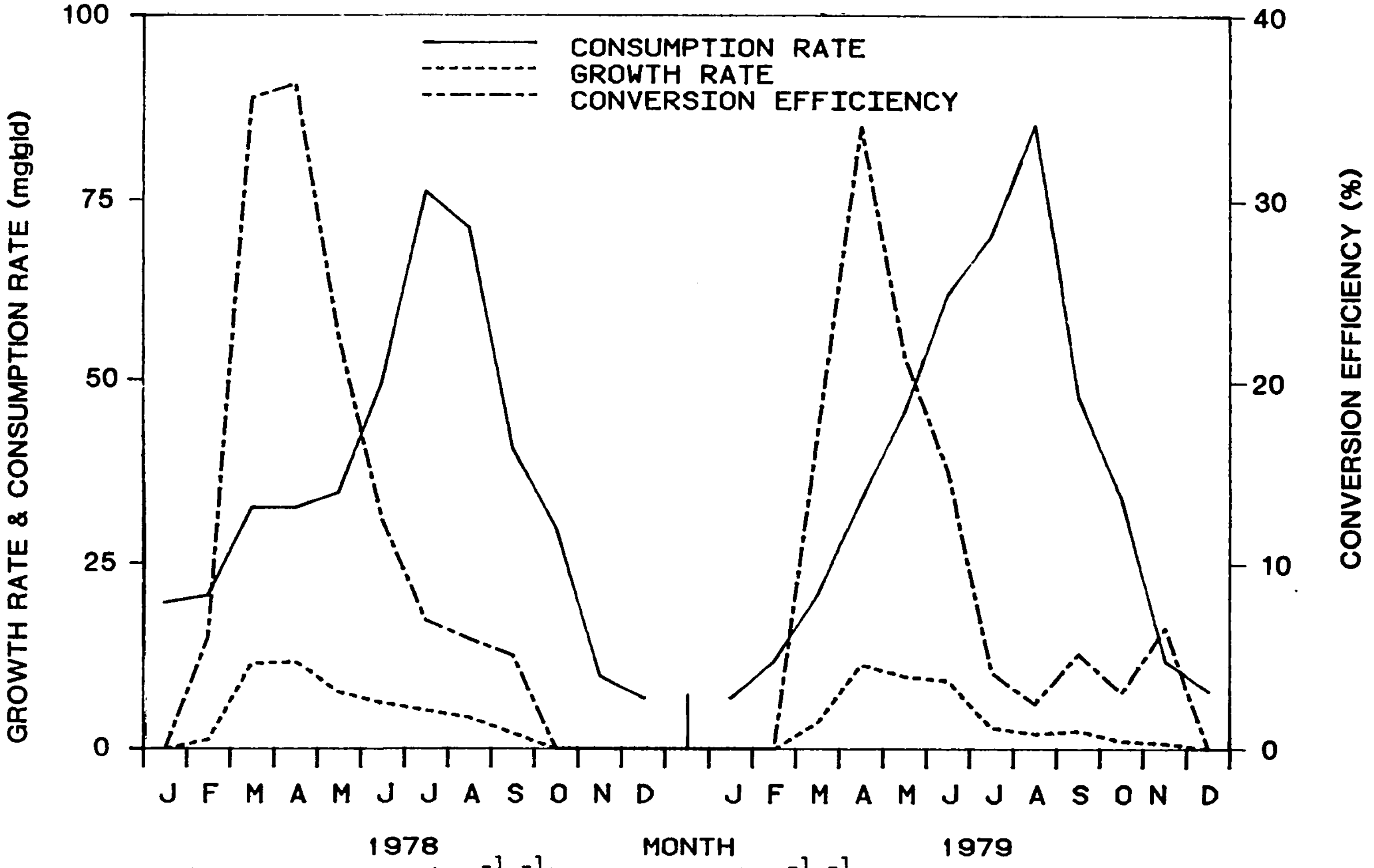

Figure 36. - Consumption rate, (mgg^{-1}d^{-1}) growth rate (mgg^{-1}d^{-1}) and gross conversion efficiency (%) of age I cutthroat trout in the lower treatment zone (section 0-500) of Bear Creek, before (1978) and after (1979) streamside timber removal.

fish and is computed as the ratio of growth rate to consumption rate (Brett and Groves 1979). A peak in the gross conversion efficiency and growth rate during spring indicates conditions (i.e., food availability and temperature) were best for growth at this time. Therefore, consumption rate must have been more than adequate to meet metabolic requirements for temperatures averaging 4°-9°C (see Appendix Table 13 for March and April). But, during summer, when water temperature peaked near 14°C, food consumption was far below the optimum for this temperature level, as indicated by the reduction in gross conversion efficiency to less than 10 percent. The reason for this low efficiency may be due to the increased demand for maintenance ration at higher temperatures, resulting in a smaller fraction of the available ration to be converted into growth. Thus, under natural conditions, the growth of cutthroat trout in Bear Creek was below the maximum level possible, except during spring, as a result of insufficient availability of food.

The response of growth to changes in temperature and to food consumption suggests that growth may be controlled or limited by density independent factors. The absence of a correlation between growth and density supports this observation as well. Growth also does not appear to be limited directly by the food supply (Figs. 30-32). Rather, growth of cutthroat trout was limited by the amount of available food relative to the amount of energy required to maintain metabolism. Metabolism is a direct function of temperature. Therefore, the control of temperature by canopy removal is an important function linking trout growth and production to riparian vegetation.

Since water temperature was not significantly different in the upper treatment zone following streamside timber removal, the results suggest changes in food availability may account for an increase in the density of age I and II trout (Figs. 35a and 36a). The increase in production of aquatic insects did not affect growth, except for age I trout during 1980. Trout consumption rates were also unchanged in the upper treatment zone compared to the control zone and pretreatment levels (Figs. 17-19). Thus, improved food availability, which was not utilized for growth, enabled an increase in population size. Similar responses of trout population abundance to changes in food abundance have been observed by McFadden (1969), Symons (1971), and Dill et al. (1981).

A problem in interpreting the results of this study is the potential effect of fish movement among adjacent stream sections or from recruitment of new fish from outside the study reach. Studies of fish movement, conducted in 1979, indicated that only 6 percent of the trout population within the study reach moved a distance greater than 50 meters, and there was no significant difference between treatment and control zones in the number of fish moving (Martin et al. 1981). However, the period of greatest movement occurred during spring and most of the fish moving were yearling cutthroat trout. Since the lower end of the study reach was blocked by a temporary weir during spring 1978 and 1979, these fish are assumed to have been recruited from waters upstream of the study area. Recruitment occurred in all three study zones (Figs. 21-23), thus the level of recruitment was assumed to represent the suitability of each zone to support additional fish. Also, since water temperature was unchanged and food supply was increased, more spring recruits were likely to be retained in the upper treatment zone throughout the summer and fall, as well.

DIFFERENCES BETWEEN THE ENERGY PATHWAY AND HABITAT CONDITIONS

The relationships linking trout production with riparian vegetation are different for the energy pathway than for habitat conditions. As demonstrated here, fish production responded to an alteration of the energy pathway through response to changes in food supply, and, through density independent control of growth in response to changes in water temperature. On the other hand, an alteration of habitat conditions may result in density independent limitation of population size and age structure in response to changes in the quantity and quality of habitat. A reduction of cover as a result of logging is known to cause reductions in the density of cutthroat trout (e.g., Narver 1972, Moring and Lantz 1975, Lestelle 1980), and the density of salmonids was increased when cover was added to streams (e.g., Chapman and Bjornn 1969, Hunt 1969). Changes in channel morphology and the loss of large woody debris as a result of logging has reduced habitat quality for larger trout, causing age composition to shift toward smaller trout (Murphy and Hall 1981, Bisson and Sedell 1982). These differences in the relationships linking fish production to riparian vegetation may explain why an alteration of the energy pathway and habitat conditions has different effects on fish production.

The effects of canopy removal on fish production were results of the interaction of density dependent and density independent mechanisms that operate in response to an alteration of the energy pathway and habitat conditions. The results of this study indicate that the net effect of canopy removal would be positive if temperature changes are small and if physical disruption of channel morphology and loss of cover are minimal. On the other hand, the results of many logging studies (e.g., Hall and Lantz 1969, Narver 1972, Scrivener and Andersen 1984) suggest that the net effect would be negative if changes in channel morphology, cover, and temperature were significant. The reduction of aquatic insect production at Station 85 as a result of channel alteration, supports the latter studies, as well. Positive responses are associated with density dependent responses to an improved food supply, which may affect the population during the spring-summer-fall growth period. Whereas the negative responses are associated with density independent responses to high temperature during summer and/or in response to an absence of cover during summer or winter, with cover being of critical importance during winter (Hartman 1965, Bustard and Narver 1975, Tschaplinski and Hartman 1983).

Since canopy removal can cause an alteration of both the energy pathway and habitat conditions, the direction and duration of the effect may depend on the time of year and how extensive each mechanism is altered. In Oregon, unshaded stream reaches had greater fish production or greater fish biomass during the summer despite an accumulation of fine sediment (Murphy et al. 1981, Hawkins et al. 1983) or a reduction of pool habitat caused by logging (Murphy and Hall 1981). Thus, positive effects caused by stimulation of the energy pathway masked the otherwise detrimental effects associated with degradation of habitat.

These positive effects, however, may be seasonal. Murphy (1984) found that high density of juvenile coho (age 1 and older) in logged streams during summer decreased below the density of coho in unlogged streams following winter as a result of the absence of large organic debris. Consequently, the negative effects associated with the loss of habitat canceled the positive effects associated with an improved food supply. Thus, the conclusion drawn from measurements of production during only the summertime could be misleading, especially if reductions of habitat quality exist.

In contrast, habitat at Bear Creek was not significantly different after canopy removal and the positive effects of an increased fish density were reflected in an increased annual production. Aho (1976) also found that annual production of cutthroat trout was significantly greater in an unshaded reach compared to a shaded reach, in which both reaches had similar habitat characteristics. Thus, the magnitude and duration of a response of fish production to changes in the energy pathway is sensitive to and dependent upon density independent limits on the fish population, which are influenced by changes in the habitat conditions.

PRODUCTION COMPARISONS WITH OTHER STREAMS

A comparison of trout production in Bear Creek with production of salmonids in other streams indicates Bear Creek is not a very productive stream (Table 14). However, direct comparisons with other streams must be treated with caution as estimates of production that contain more than one species are a more accurate measure of a streams productivity. Mack Creek is probably the most similar in species composition to Bear Creek, as it only contained cutthroat trout and one cottid species. Bear Creek contained *Cottus asper* in addition to cutthroat trout. Comparisons between these streams indicate that streams in the western Cascade Mountains of Oregon may be more productive than streams on the western slope of the Olympic Mountains. Also, the effects of canopy removal may be greater in Mack Creek compared to Bear Creek.

Table 14

Production estimates for trout and salmon in Bear Creek and other streams ($gm^{-2}yr^{-1}$).

Stream	Species	Production	Reference
Bear Cr., Wash.	S. clarki	1.6-2.5	This study
Valley Cr., Minn.	S. fontinalis	4.4-6.1	Elwood Waters, 1979
Lawrence Cr., Wis.	S. fontinalis	10.6-12.5	Hunt 1974
Big Springs Cr., Idaho	S. gairdneri and S. fontinalis	11.8	Goodnight and Bjornn, 1971
Deer Creek, Ore.	S. clarki	4.0	Lowry 1966
Flynn Creek, Ore.	S. clarki	4.9	Lowry 1966
Needle Branch Creek, Ore.	S. clarki	3.5	Lowry 1966
Deer Creek, Ore.	S. clarki, S. gairdneri, and O. kisutch	16.0	Chapman 1965
Mack Creek, Ore.	S. clarki	2.6-7.5[a]	Aho 1976

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[a] Lower and upper values represent production in shaded and unshaded stream sections, respectively.

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APPENDIX: TABLES

Appendix Table 1

Average production to biomass ratio for benthic macroinvertebrates based on average annual biomass and annual production estimates determined from four streams in the Clearwater River during 1973-1974, data from Martin (1976)

Stream	Condition of Riparian	Annual Mean Biomass (gm^{-2}, wet wt.)	Annual Production (gm^{-2}, wet wt.)	Production/ Biomass Ratio
Stequaleho Creek	Old growth	3.03	16.10	5.31
Shale Creek	Second growth	2.30	11.62	5.05
Christmas Creek	Clearcut	2.29	12.55	5.48
West Fork Snahapish River	Clearcut old growth	4.14	20.58	4.97
		Average P/B ratio		5.20

Appendix Table 2

Estimates of maintenance ration, mean weight, and mean temperature used to develop a regression model for predicting daily maintenance ration

Age Group	Date	Mean Temperature (°C)	Mean Weight (g)	Relative Growth Rate[a] (G) (calg^{-1}d^{-1})	Daily Mean Consumption (C) (calg^{-1}d^{-1})	Daily Maintenance Ration (C-G) (calg^{-1}d^{-1})
0	07/06/78	12.7	2.23	5.88	119.06	113.18
	08/02/78	11.8	2.35	13.07	146.38	133.31
	08/30/78	13.2	2.66	5.66	130.85	125.19
	09/29/78	11.1	3.41	1.95	58.07	56.12
	11/11/78	5.2	3.40	0	14.14	14.14
I	02/22/78	6.0	2.61	1.40	12.35	10.95
	04/04/78	5.8	3.39	11.38	27.39	16.01
	04/28/78	7.6	4.70	11.98	32.74	20.76
	05/23/78	8.2	5.07	7.56	33.35	25.79
	07/06/78	12.7	9.66	6.32	45.94	39.62
	08/02/78	11.8	8.86	5.14	58.50	53.36
	08/30/78	13.2	9.13	4.13	63.75	59.62
	09/29/78	11.1	10.23	2.09	57.63	55.54
	11/11/78	5.2	11.35	0	8.78	8.78
II	02/22/78	6.0	9.99	0	14.48	14.48
	04/04/78	5.8	10.86	3.62	20.85	17.23
	04/28/78	7.6	13.28	6.18	23.95	17.77
	05/23/78	8.2	12.70	6.04	26.33	20.29
	07/06/78	12.7	17.72	6.11	36.43	30.32

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[a] Based on nearest monthly instantaneous growth rates where: relative growth = $G_x \cdot 10^3/t$ (days) and 1 mg fish = 1 cal.

Appendix Table 3

Daily mean weight of stomach contents, stomach evacuation rate, and daily food consumption for cutthroat trout in Bear Creek during 1978

Sample Date	Age Group	Daily Mean Stomach Weight[a] (S) (mgg^{-1})	Mean Temperature (T) (°C)	Evacuation Rate[b] (R)	Daily Consumption[c] (C) (mgg^{-1}d^{-1})
07/06/78	0	22.55	12.7	.220	119.06
08/02/78	0	30.65	11.8	.199	146.38
08/30/78	0	23.50	13.2	.232	130.85
09/29/78	0	13.15	11.1	.184	58.07
11/11/78	0	6.20	5.2	.095	14.14
02/22/78	1	4.95	6.0	.104	12.35
04/04/78	1	11.30	5.8	.101	27.39
04/28/78	1	11.00	7.6	.124	32.74
05/23/78	1	10.45	8.2	.133	33.35
07/06/78	1	8.70	12.7	.220	45.94
08/02/78	1	12.25	11.8	.199	58.50
08/30/78	1	11.45	13.2	.232	63.75
09/29/78	1	13.05	11.1	.184	57.63
11/11/78	1	3.85	5.2	.095	8.78
02/22/78	2	5.80	6.0	.104	14.48
04/04/78	2	8.60	5.8	.101	20.85
04/28/78	2	8.05	7.6	.124	23.95
05/23/78	2	8.25	8.2	.133	26.33
07/06/78	2	6.90	12.7	.220	36.43

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[a] Dry weight converted to wet weight using 5:1 conversion ratio (IBP 1971).

[b] Computed from equation: $R = 0.053e^{0.112T}$, see methods for explanation.

[c] Computed from equation: C = 24Sr, see methods for explanation.

Appendix Table 4

Age 0 cutthroat trout stomach sampling times, mean weight of stomach contents (dry weight food per wet weight fish), and daily mean weight of stomach contents for Bear Creek during 1978

Sample Date	Sample Time	Time Weighting Factor (Ai) (Hr)	n	Interval Mean Stomach Weight (Si) ± SD (mgg^{-1})	Ai x Si (mgg^{-1}t^{-1})	Daily Mean Stomach Weight (S) (mgg^{-1})
07/06/78	03:48	6.33	7	3.74 ± 2.22	23.67	
	11:05	6.75	11	5.51 ± 2.70	37.19	
	17:17	5.65	8	5.08 ± 2.07	28.70	
	22:23	5.27	7	3.57 ± 1.03	18.81	
		24.00	33		108.37	4.51
08/02/78	05:32	6.53	6	5.73 ± 1.96	37.41	
	10:48	5.67	6	4.08 ± 1.81	23.13	
	16:32	5.30	6	7.13 ± 1.79	37.79	
	21:24	6.50	11	7.51 ± 2.53	48.81	
		24.00	29		147.14	6.13
08/30/78	06:20	6.43	10	5.02 ± 2.78	32.28	
	10:38	4.72	10	3.53 ± 3.77	16.66	
	15:46	5.55	9	3.39 ± 1.57	18.81	
	21:45	7.30	18	6.17 ± 5.06	45.04	
		24.00	47		112.79	4.70
09/29/78	07:45	6.85	10	1.95 ± 1.56	13.36	
	12:27	4.45	14	1.55 ± 1.09	6.89	
	16:39	5.15	11	2.78 ± 1.85	14.32	
	22:45	7.55	12	3.79 ± 2.57	28.61	
		24.00	47		63.18	2.63
11/11/78	09:06	5.53	14	1.09 ± 0.80	6.03	
	14:35	6.04	18	1.13 ± 1.42	6.82	
	21:09	12.43	12	1.37 ± 0.99	17.02	
		24.00	44		29.88	1.24

Appendix Table 5

Age 1 cutthroat trout stomach sampling times, mean weight of stomach contents (dry weight food per wet weight fish), and daily mean weight of stomach contents for Bear Creek during 1978

Sample Date	Sample Time	Time Weighting Factor (Ai) (Hr)	n	Interval Mean Stomach Weight (Si) ± SD (mgg^{-1})	Ai x Si ($mgg^{-1}t^{-1}$)	Daily Mean Stomach Weight (S) (mgg^{-1})
02/22/78	07:30	6.25	2	1.03 ± 0.10	6.43	
	12:00	5.50	2	1.22 ± 1.71	6.71	
	16:30	4.75	4	0.92 ± 1.44	4.37	
	23:30	7.50	4	0.85 ± 0.54	6.38	
		24.00	12		23.89	0.99
04/04/78	01:28	4.78	3	4.85 ± 0.98	23.18	
	07:03	5.38	5	0.78 ± 0.45	4.20	
	13:13	7.82	9	1.65 ± 1.08	12.90	
	21:28	6.02	6	2.34 ± 1.85	14.09	
		24.00	23		54.37	2.26
04/28/78	06:01	4.41	6	1.88 ± 1.08	8.29	
	07:36	2.70	3	3.26 ± 0.73	8.80	
	13:00	5.36	4	1.96 ± 0.53	10.45	
	16:43	3.40	12	4.15 ± 2.47	14.11	
	19:50	3.03	2	1.04 ± 0.61	3.15	
	22:45	5.10	7	1.56 ± 0.59	7.96	
		24.00	34		52.76	2.20
05/23/78	04:39	5.88	9	1.63 ± 0.92	9.58	
	09:45	4.76	4	1.96 ± 0.91	9.33	
	14:09	4.58	5	2.41 ± 1.38	10.99	
	18:56	3.93	8	2.41 ± 0.58	9.47	
	22:00	4.85	11	2.22 ± 1.03	10.77	
		24.00	37		50.14	2.09
07/06/78	03:48	6.33	12	1.36 ± 0.95	8.61	
	11:05	6.75	17	1.88 ± 1.47	12.69	
	17:17	5.65	18	1.48 ± 0.72	8.36	
	22:23	5.27	12	2.29 ± 1.25	12.07	
		24.00	59		41.73	1.74

Appendix Table 5 (Continued)

Sample Date	Sample Time	Time Weighting Factor (Ai) (Hr)	n	Interval Mean Stomach Weight (Si) ± SD (mgg^{-1})	Ai x Si ($mgg^{-1}t^{-1}$)	Daily Mean Stomach Weight (S) (mgg^{-1})
08/02/78	05:32	6.53	10	2.12 ± 0.71	13.84	
	10:48	5.67	10	1.30 ± 0.86	7.37	
	16:32	5.30	10	2.01 ± 0.56	10.65	
	21:24	6.50	10	4.16 ± 2.03	27.04	
		24.00	40		58.91	2.45
08/30/78	06:20	6.43	6	1.96 ± 0.97	12.60	
	10:38	4.72	10	3.33 ± 1.81	15.72	
	15:46	5.55	10	2.24 ± 2.25	12.43	
	21:45	7.30	2	1.96 ± 0.47	14.31	
		24.00	28		55.06	2.29
09/29/78	07:45	6.85	10	1.89 ± 1.75	12.94	
	12:27	4.45	6	1.55 ± 1.44	6.94	
	16:39	5.15	8	2.78 ± 2.25	14.31	
	22:45	7.55	8	3.78 ± 5.15	28.53	
		24.00	32		62.72	2.61
11/11/78	09:06	5.53	6	0.87 ± 1.35	4.81	
	14:35	6.04	4	0.17 ± 0.16	1.02	
	21:09	12.43	10	1.01 ± 1.54	12.55	
		24.00	20		18.39	0.77

Appendix Table 6

Age 2 cutthroat trout stomach sampling times, mean weight of stomach contents (dry weight food per wet weight fish), and daily mean weight of stomach contents for Bear Creek during 1978

Sample Date	Sample Time	Time Weighting Factor (Ai) (Hr)	n	Interval Mean Stomach Weight (Si) ± SD (mgg^{-1})	Ai x Si (mgg^{-1}t^{-1})	Daily Mean Stomach Weight (S) (mgg^{-1})
02/22/78	07:30	6.25	7	1.94 ± 0.84	12.12	
	12:00	5.50	6	1.44 ± 0.92	7.92	
	16:30	4.75	3	0.35 ± 0.30	1.66	
	23:30	7.50	5	0.83 ± 1.08	6.23	
		24.00	21		27.93	1.16
04/04/78	01:28	4.78	11	1.48 ± 0.94	7.07	
	07:03	5.38	10	0.88 ± 0.54	4.73	
	13:13	5.76	6	1.26 ± 0.80	7.26	
	17:33	4.12	4	2.45 ± 2.51	10.09	
	21:28	3.96	9	3.02 ± 2.21	11.96	
		24.00	40		41.12	1.72
04/28/78	06:01	4.41	6	1.21 ± 0.43	5.34	
	07:36	2.70	8	1.78 ± 0.78	4.81	
	13:00	5.36	12	2.05 ± 1.50	10.99	
	16:43	3.40	8	1.64 ± 1.02	5.58	
	15:50	3.03	4	1.23 ± 1.29	3.73	
	22:45	5.10	9	1.59 ± 0.94	8.11	
		24.00	47		38.56	1.61
05/23/78	04:39	5.88	8	1.61 ± 1.25	9.47	
	09:45	4.76	10	1.75 ± 1.55	8.33	
	14:09	4.58	6	1.46 ± 0.88	6.69	
	18:56	3.93	3	2.48 ± 2.87	9.75	
	22:00	4.85	7	1.10 ± 0.65	5.33	
		24.00	34		39.57	1.65
07/06/78	03:48	6.33	5	1.48 ± 1.09	9.37	
	11:05	6.75	2	1.51 ± 1.19	10.19	
	17:17	5.65	1	1.27	7.17	
	22:23	5.27	2	1.21 ± 0.58	6.38	
		24.00	10		33.11	1.38

Appendix Table 7

Mean insect fallout density (no.m^{-2} d^{-1}) by size group
for treatment (Sections 0-500, 500-1,000) and control (Section 1,000-1,200)
zones of Bear Creek before (1978) and after (1979) streamside timber removal

Size Group (mm)	Median Sample Date																	
	Pretreatment (1978)							Posttreatment (1979)										
	5-20 (6)a/	6-24 (7)	7-1 (7)	7-28 (7)	8-17 (7)	8-25 (7)	Mean	4-21 (6)	5-20 (6)	5-27 (8)	6-17 (8)	6-24 (6)	7-22 (8)	7-28 (5)	8-24 (8)	9-17 (6)	9-23 (6)	Mean
	Lower Treatment Zone (Section 0-500)																	
0-3		60.2	66.3	43.4	20.7	6.4		15.4	15.2	33.0	84.9	72.4	96.0	82.4	60.4	41.1	27.0	
3-6		10.1	14.8	37.8	9.8	11.7		7.6	6.8	8.7	6.8	14.9	31.7	16.8	23.6	12.9	7.5	
6-9		6.2	4.8	4.3	1.8	1.8		3.2	4.5	4.6	3.6	6.5	3.9	2.1	1.8	5.4	6.2	
9-12		0.7	2.1	2.8	0.9	1.8		2.3	1.6	1.7	0.5	2.9	1.2	1.4	1.1	0.8	0.8	
>12		0.9	0.3	1.4	0.3	0.3		0.0	0.6	0.7	0.0	0.3	0.2	0.7	1.4	0.0	0.0	
Combined		78.1	88.3	89.7	33.5	22.0	62.3	28.5	28.7	48.7	95.8	97.0	133.0	103.4	88.3	60.2	41.5	72.5
	Upper Treatment Zone (Section 500-1,000)																	
0-3	21.2	39.3	78.6	38.6	20.4	4.2		13.5	27.7	55.4	93.8	107.0	81.1	98.8	17.0	40.0	27.4	
3-6	8.8	12.0	17.3	43.2	16.2	8.2		6.5	8.1	13.5	10.3	17.9	22.3	18.2	16.6	8.0	4.1	
6-9	8.4	40.4	5.6	3.1	2.6	2.5		5.1	6.4	7.0	5.9	9.3	5.1	5.5	2.3	3.6	3.2	
9-12	0.6	0.1	2.3	8.6	1.7	0.1		1.0	1.0	1.4	1.7	2.5	1.5	5.5	2.0	1.9	0.5	
>12	0.3	0.3	0.3	0.8	0.5	1.4		1.0	0.6	0.4	0.0	0.2	0.8	0.7	0.5	0.5	1.4	
Combined	39.3	92.1	104.1	94.3	41.4	16.4	64.6	27.1	43.8	77.7	111.7	136.9	110.8	128.7	38.4	54.0	36.6	76.5
	Control Zone (Section 1,000-1,200)																	
0-3	41.6	115.1	102.2	37.8	17.0	13.8		19.0	37.2	71.1	138.8	163.5	111.3	148.7	19.2	43.6	25.6	
3-6	17.0	25.3	16.2	36.5	19.9	12.9		11.9	10.5	9.6	15.3	25.6	31.4	33.5	18.0	9.9	3.5	
6-9	6.2	14.1	7.9	4.1	2.5	2.9		8.0	3.5	6.5	2.6	8.7	3.0	3.5	1.7	2.9	4.6	
9-12	1.2	1.2	4.1	13.3	1.2	0.8		1.5	0.6	2.2	0.4	0.6	7.4	2.8	2.3	1.2	0.6	
>12	0.4	0.0	0.8	0.0	0.0	0.0		0.5	0.0	0.0	0.4	0.0	0.4	0.7	0.6	1.7	0.0	
Combined	66.4	155.7	131.2	91.7	40.6	30.4	86.0	40.9	51.8	89.4	157.5	198.4	153.5	189.2	41.8	59.3	34.3	101.6

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a/ Length of sample period, days.

Appendix Table 8

Insect fallout biomass ($mgm^{-2}d^{-1}$, weight wet) by size group for treatment (Sections 0-500, 500-1,000) and control (Section 1,000-1,200) zones of Bear Creek before (1978) and after (1979) streamside timber removal

	Median Sample Date																
	Pretreatment (1978)							Posttreatment (1979)									
Size Group (mm)	5-20 (6)a/	6-24 (7)	7-1 (7)	7-28 (7)	8-17 (7)	8-25 (7)	Mean	4-21 (6)	5-20 (6)	5-27 (8)	6-17 (8)	6-24 (6)	7-22 (8)	7-28 (5)	8-24 (8)	9-17 (6)	9-23 (6)	Mean
Lower Treatment Zone (Section 0-500)																	
0-3		31.7	26.3	13.3	12.7	2.9		7.6	5.5	11.4	11.4	18.7	28.9	25.1	15.1	10.6	5.9	
3-6		30.9	34.1	139.5	33.7	35.5		37.3	25.0	25.3	30.9	46.3	74.6	24.8	56.8	24.9	17.3	
6-9		111.5	46.9	78.6	21.1	14.8		43.8	33.8	62.4	17.8	37.7	45.4	15.2	14.3	49.1	55.7	
9-12		35.4	113.7	195.5	41.1	87.9		63.2	42.2	50.3	25.4	90.4	83.5	13.5	38.0	29.8	34.1	
>12		136.2	32.1	128.8	54.2	5.9		0.0	66.1	118.2	0.0	6.5	7.0	67.8	97.6	0.0	0.0	
Combined		345.7	253.1	555.7	162.8	147.0	292.9	151.9	172.6	267.6	85.5	199.6	239.4	146.4	221.8	114.4	113.0	171.2
Upper Treatment Zone (Section 500-1,000)																	
0-3	6.2	23.1	31.5	11.9	7.8	1.8		5.0	10.9	17.5	21.5	35.2	19.1	20.5	8.1	9.0	4.3	
3-6	27.5	28.5	34.0	168.7	50.4	30.5		30.5	29.0	52.8	30.4	71.2	76.7	50.7	49.1	19.4	9.5	
6-9	126.0	152.7	125.2	36.5	17.3	20.2		73.2	54.0	53.0	26.0	49.5	54.0	41.2	12.4	26.3	31.6	
9-12	27.3	3.6	62.0	577.7	105.7	2.9		37.3	16.8	49.9	62.1	102.9	79.2	387.7	198.3	148.8	3.1	
>12	79.1	108.0	53.9	103.8	169.6	88.5		21.4	65.2	34.1	0.0	41.4	77.7	85.5	101.6	8.5	239.1	
Combined	266.1	315.9	306.6	898.6	350.8	143.9	380.2	167.4	175.9	207.3	140.0	300.2	306.7	585.6	369.5	212.0	287.6	275.2
Control Zone (Section 1,000-1,200)																	
0-3	12.7	44.5	43.4	14.0	7.7	2.4		2.5	10.1	22.2	48.4	63.2	24.6	30.4	7.3	13.8	8.8	
3-6	60.9	100.5	70.4	156.1	58.5	39.9		27.4	48.7	39.7	58.9	62.3	160.5	100.5	36.6	34.9	10.8	
6-9	42.4	336.1	135.7	56.6	19.5	11.1		33.7	23.0	35.9	40.8	90.9	17.0	20.9	59.2	10.7	52.3	
9-12	53.2	480.4	160.6	772.8	88.6	47.6		34.4	2.4	21.1	21.5	7.5	407.8	179.7	196.8	89.2	57.6	
>12	18.8	0.0	71.0	0.0	0.0	0.0		7.7	0.0	0.0	22.3	0.0	58.3	71.2	24.8	171.6	0.0	
Combined	188.0	961.5	481.1	999.5	174.3	101.0	484.2	105.7	84.2	118.9	191.9	223.9	668.2	402.7	324.7	320.2	129.5	256.9

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a/ Length of sample period, days.

Appendix Table 9

Numeric Composition (no.$m^{-2}d^{-1}$) of insect fallout
by taxonomic group for Bear Creek

Taxonomic Group	Median Sample Date															
	Pretreatment (1978)						Posttreatment (1979)									
	5-20	6-24	7-1	7-28	8-17	8-25	4-21	5-20	5-27	6-17	6-24	7-24	7-28	8-24	9-17	9-23
Lower Treatment Zone (Section 0-500)																
Ephemeroptera	--	2.0	1.4	0.7	--	--	0.9	2.6	1.7	2.2	4.8	1.2	0.7	--	0.8	0.4
Plecoptera	--	1.4	0.5	1.1	1.1	1.4	2.9	1.6	2.2	1.4	2.6	0.7	--	0.4	5.4	2.9
Trichoptera	--	1.1	0.2	0.9	0.3	0.5	0.3	0.6	0.7	0.5	0.3	1.0	1.4	1.1	--	0.8
Diptera	--	26.9	50.2	69.8	21.9	12.1	16.3	15.5	33.7	83.7	66.3	113.5	76.8	64.4	37.8	27.8
Coleoptera	--	35.3	24.6	5.5	2.1	1.8	5.5	4.8	3.9	0.7	6.1	1.9	13.3	6.2	3.3	1.2
Orthoptera	--	2.3	2.0	3.4	0.3	0.5	--	--	0.2	--	0.3	0.7	--	--	--	--
Collembola	--	--	--	--	1.2	0.2	--	--	--	0.5	0.3	--	--	0.7	2.1	0.8
Hymenoptera	--	--	1.6	3.6	0.9	0.9		0.3	1.0	1.9	1.6	1.4	1.4	9.8	0.4	2.1
Hemiptera	--	0.2	0.9	2.1	0.9	1.2	0.6	2.2	2.7	4.6	10.0	6.5	5.6	3.3	3.7	1.7
Posocoptera	--	--	--	--	0.9	0.2	--	--	--	--	1.6	0.5	0.7	--	0.4	--
Isoptera	--	--	--	--	--	0.2	--	--	--	--	--	--	--	--	--	--
Microcoryphia	--	0.2	--	--	0.2	0.5	--	--	0.2	--	0.3	--	0.7	--	--	--
Chilopoda	--	0.2	--	--	--	--	--	--	--	--	--	--	--	0.4	--	--
Lepidoptera	--	--	--	0.2	--	--	--	--	--	--	--	0.2	--	--	--	--
Araneae	--	8.7	6.9	2.5	3.6	2.1	2.0	1.0	2.4	0.2	2.6	5.3	2.8	2.2	6.2	3.7
Oligochaeta	--	--	--	--	--	0.3	--	--	--	--	--	--	--	--	--	--
Total		78.2	88.4	89.8	33.5	22.1	28.5	28.8	48.7	95.8	97.0	133.1	103.4	88.4	60.3	41.6
Percent Aquatic[a]		5.8	2.4	3.0	4.2	8.6	14.4	16.7	9.4	4.3	7.9	2.2	2.0	1.7	10.3	9.9
Upper Treatment Zone (Section 500-1,000)																
Ephemeroptera	1.9	1.2	0.9	0.5	--	--	0.2	2.5	3.9	3.1	3.1	2.8	1.5	0.3	1.4	0.2
Plecoptera	0.9	0.8	1.5	0.9	1.9	1.5	5.1	3.5	2.9	3.1	3.5	1.5	2.0	2.0	2.4	1.2
Trichoptera	0.5	0.5	0.9	0.3	0.3	--	0.3	0.4	0.7	0.6	2.5	1.5	1.0	1.0	0.4	--
Diptera	27.3	46.1	55.2	65.3	28.5	9.8	15.0	27.0	58.0	93.8	97.9	85.1	96.5	24.0	32.5	24.5
Coleoptera	2.0	35.1	35.4	7.8	2.5	0.9	2.2	3.5	2.1	0.6	3.3	3.7	6.2	2.9	1.9	1.2
Orthoptera	2.6	5.0	3.3	8.2	1.1	0.6	0.3	0.2	0.3	0.5	1.4	0.9	4.2	1.2	1.0	1.4
Collembola	--	--	--	0.3	0.1	--	0.2	--	--	0.5	0.8	--	0.7	0.3	6.1	2.4
Hymenoptera	0.9	0.1	1.2	1.7	1.4	1.1	0.3	2.1	1.9	2.8	4.1	3.0	4.0	2.4	2.4	1.7
Hemiptera	--	0.1	0.5	1.4	1.1	0.9	0.7	3.7	6.2	4.5	15.2	8.9	5.7	2.5	2.4	1.0
Posocoptera	--	--	--	4.4	2.2	0.1	--	--	--	0.5	0.2	0.6	1.2	0.3	--	0.2
Isoptera	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	0.2	--
Microcoryphia	--	--	--	--	--	0.1	--	--	--	--	--	0.1	0.5	0.5	--	--
Chilopoda	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	0.2	--
Lepidoptera	--	--	0.1	0.1	0.3	--	--	--	--	--	0.2	--	0.5	0.1	--	--
Araneae	3.1	3.1	5.0	3.3	1.9	1.1	2.2	1.0	1.6	1.5	4.6	2.5	4.5	0.9	2.9	2.7
Oligochaeta	0.1	--	--	--	--	0.1	0.7	--	--	--	--	--	--	--	--	--
Total	39.4	92.1	104.1	94.3	41.5	16.5	27.1	43.8	77.8	111.8	136.9	110.8	128.7	38.6	54.1	36.6
Percent Aquatic	8.4	2.7	3.2	1.8	5.3	9.1	21.4	14.6	9.6	6.1	6.6	5.2	3.5	8.5	7.8	3.8

Appendix Table 9 (Continued)

Taxonomic Group	Median Sample Date															
	Pretreatment (1978)						Posttreatment (1979)									
	5-20	6-24	7-1	7-28	8-17	8-25	4-21	5-20	5-27	6-17	6-24	7-24	7-28	8-24	9-17	9-23
Control Zone (Section 1,000-1,200)																
Ephemeroptera	2.1	0.4	--	--	--	--	--	1.2	2.2	0.4	1.2	--	--	--	--	--
Plecoptera	5.4	1.7	1.7	0.4	1.2	2.1	13.0	2.9	4.8	1.3	4.1	2.2	2.1	0.6	1.7	0.6
Trichoptera	--	0.8	--	0.8	--	0.4	0.5	--	--	0.4	0.6	0.9	1.4	--	0.6	--
Diptera	47.8	110.6	86.5	61.9	28.3	19.9	20.4	42.5	75.1	147.5	177.5	122.2	154.3	29.7	32.0	18.6
Coleoptera	3.3	27.4	27.8	6.6	2.5	2.9	2.0	1.2	2.2	0.9	1.2	2.2	4.9	1.7	1.2	3.5
Orthoptera	--	8.7	4.9	10.4	0.8	0.4	--	--	--	--	0.6	5.2	2.1	1.2	0.6	--
Collembola	--	--	0.4	--	0.4	--	1.5	0.6	--	1.7	0.6	3.0	3.5	--	9.3	3.5
Hymenoptera	1.2	1.7	1.2	2.1	2.9	2.5	--	1.7	0.9	0.4	1.7	3.9	5.6	3.5	6.4	1.7
Hemiptera	--	--	2.1	0.4	0.8	--	0.5	--	2.2	2.2	7.6	10.0	7.0	0.6	1.1	1.7
Posocoptera	--	--	--	6.2	2.1	0.8	--	--	--	0.4	--	2.2	7.7	0.6	0.6	--
Isoptera	--	--	--	--	--	--	--	--	--	--	--	--	--	0.6	--	--
Microcoryphia	0.4	--	1.2	0.4	--	--	--	--	--	--	--	0.4	0.7	--	--	--
Chilopoda	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidoptera	--	--	--	--	--	--	--	--	--	--	--	--	--	0.6	0.6	--
Araneae	6.2	4.6	5.4	2.5	1.7	1.2	2.5	1.7	2.2	2.2	3.5	1.3	--	2.9	5.2	4.6
Oligochaeta	--	--	--	--	--	--	0.5	--	--	--	--	--	--	--	--	--
Total	66.5	155.9	131.4	91.9	40.7	30.3	40.9	51.8	89.5	157.6	198.5	153.6	189.3	41.9	59.4	34.3
Percent Aquatic	11.3	1.9	1.3	1.3	2.9	8.2	33.0	7.9	7.8	1.3	3.0	2.0	1.8	1.4	3.9	1.7

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a/ Includes adult Ephemeroptera, Plecoptera, and Trichoptera.

Appendix Table 10

Gravimetric composition ($mgm^{-2}d^{-1}$, wet weight) of insect fallout by taxonomic group for Bear Creek

Taxonomic Group	Median Sample Date															
	Pretreatment (1978)						Posttreatment (1979)									
	5-20	6-24	7-1	7-28	8-17	8-25	4-21	5-20	5-27	6-17	6-24	7-24	7-28	8-24	9-17	9-23
Lower Treatment Zone (Section 0-500)																
Ephemeroptera	--	5.5	4.5	1.3	--	--	9.0	7.4	5.6	3.7	11.6	2.8	0.2	3.3	2.9	2.5
Plecoptera	--	58.8	1.5	8.6	3.0	3.0	10.6	14.0	11.1	4.9	13.7	8.3	--	--	6.4	6.2
Trichoptera	--	24.1	5.0	7.6	2.7	4.9	1.0	2.1	23.6	3.0	3.2	2.9	10.9	7.8	--	2.4
Diptera	--	57.3	84.9	214.6	37.8	39.1	97.4	23.1	44.0	47.7	53.6	108.3	40.3	66.1	87.1	90.8
Coleoptera	--	19.9	28.1	9.6	42.5	16.7	23.6	80.8	147.5	21.2	90.9	1.6	13.7	24.1	2.3	2.7
Orthoptera	--	137.0	113.8	225.1	29.8	46.0	--	--	7.6	--	9.7	52.2	--	0.2	--	--
Collembola	--	--	--	--	0.2	<0.1	--	--	--	<0.1	<0.1	--	--	--	0.7	0.2
Hymenoptera	--	--	0.4	1.5	17.8	0.4	--	34.8	2.4	1.2	0.3	28.6	67.9	67.7	0.1	1.1
Hemiptera	--	<0.1	1.3	12.9	10.8	8.4	2.7	5.2	3.2	3.8	10.0	20.8	7.7	32.9	3.7	2.7
Posocoptera	--	--	--	--	1.3	<0.1	--	--	--	--	0.7	0.1	0.3	--	0.1	--
Isoptera	--	--	--	--	--	3.7	--	--	--	--	--	--	--	--	--	--
Microcoryphia	--	<0.1	--	--	5.9	9.2	--	--	4.5	--	0.2	--	4.9	--	--	--
Chilopoda	--	12.8	--	--	--	--	--	--	--	--	--	--	--	13.3	--	--
Lepidoptera	--	--	--	69.9	--	--	--	--	--	--	--	2.9	--	--	--	--
Araneae	--	29.9	13.8	4.6	10.8	9.5	7.7	5.3	18.1	<0.1	5.6	10.6	0.5	6.2	11.2	4.4
Oligochaeta	--	--	--	--	--	5.9	--	--	--	--	--	--	--	--	--	--
Total	--	345.9	253.3	555.8	162.7	147.0	151.9	172.7	267.7	85.6	199.7	239.5	146.4	221.8	114.5	113.1
Percent Aquatic[a]	--	25.5	4.3	3.2	3.5	5.4	13.8	13.3	14.9	14.0	14.0	5.9	7.5	5.0	7.8	9.7
Upper Treatment Zone (Section 500-1,000)																
Ephemeroptera	8.1	3.9	2.9	1.2	--	--	1.2	10.6	20.9	8.9	10.5	3.5	2.8	0.9	2.7	0.1
Plecoptera	8.8	2.7	47.2	3.5	4.8	2.0	41.3	35.1	18.7	16.8	13.5	6.7	6.9	3.5	11.3	3.5
Trichoptera	2.6	4.6	6.3	1.6	4.6	--	6.9	2.3	4.4	9.7	15.5	9.5	5.9	2.6	0.4	--
Diptera	152.8	37.0	79.2	235.6	69.9	27.1	78.4	45.1	88.9	54.4	84.3	87.7	62.8	42.7	42.4	29.1
Coleoptera	10.4	18.8	37.1	3.8	1.6	12.1	5.4	16.0	17.3	3.3	57.4	32.1	50.7	23.1	4.0	0.5
Orthoptera	66.9	237.9	119.2	631.5	88.8	56.7	7.3	6.6	17.2	19.1	76.6	62.7	369.2	174.3	125.9	196.7
Collembola	--	--	--	<0.1	<0.1	--	<0.1	--	--	0.1	0.4	--	<0.1	0.2	1.2	0.4
Hymenoptera	4.4	<0.1	1.3	1.6	22.5	2.2	0.1	54.4	22.5	18.5	3.7	66.9	54.5	85.9	0.4	48.0
Hemiptera	--	<0.1	0.2	1.8	3.1	6.1	9.5	3.7	11.7	4.6	16.3	28.4	13.9	13.4	3.1	2.8
Posocoptera	--	--	--	0.6	0.3	<0.1	--	--	--	0.2	<0.1	0.6	0.9	0.3	--	<0.1
Isoptera	--	--	--	--	--	--	--	--	--	2.9	--	--	--	--	5.7	--
Microcoryphia	--	--	--	--	--	2.9	--	--	--	--	--	4.5	5.4	14.4	--	--
Chilopoda	--	--	--	--	1.7	--	--	--	--	--	--	--	--	--	3.4	--
Lepidoptera	--	--	6.3	3.8	147.4	--	--	--	--	--	6.3	--	5.9	0.4	--	--
Araneae	9.5	10.7	6.7	13.6	5.9	20.6	13.2	2.0	5.6	1.3	15.6	3.8	6.6	7.8	11.2	6.2
Oligochaeta	2.6	--	--	--	--	14.3	4.0	--	--	--	--	--	--	--	--	--
Total	266.2	315.9	306.7	898.7	350.7	144.0	167.4	176.0	207.3	140.0	300.2	306.6	585.6	369.4	212.1	287.5
Percent Aquatic	7.5	3.5	18.2	0.7	2.6	1.4	29.3	27.3	21.2	25.0	13.0	6.2	2.6	1.9	6.6	1.0

Appendix Table 10 (Continued)

Taxonomic Group	Median Sample Date															
	Pretreatment (1978)						Posttreatment (1979)									
	5-20	6-24	7-1	7-28	8-17	8-25	4-21	5-20	5-27	6-17	6-24	7-24	7-28	8-24	9-17	9-23
Control Zone (Section 1,000-1,200)																
Ephemeroptera	7.1	1.9	--	--	--	--	--	14.8	10.3	0.1	0.9	--	--	--	--	--
Plecoptera	42.3	12.6	6.7	1.5	3.0	4.9	50.6	10.5	29.1	2.5	19.5	12.5	3.5	0.7	10.6	0.1
Trichoptera	--	3.4	--	7.3	--	1.1	1.1	--	--	22.3	1.4	1.1	2.5	--	149.3	--
Diptera	54.8	136.6	132.5	237.4	79.7	34.8	32.9	34.7	56.7	101.4	137.4	172.0	102.4	38.9	20.1	20.7
Coleoptera	53.1	18.4	98.5	24.2	0.8	21.6	5.2	3.1	5.9	--	7.6	4.0	11.5	2.3	0.8	1.5
Orthoptera	--	762.2	186.0	698.8	76.0	29.6	--	--	--	28.1	22.5	358.5	167.6	104.1	71.4	--
Collembola	--	--	<0.1	--	<0.1	--	2.1	<0.1	--	0.6	<0.1	0.4	0.3	--	1.8	0.7
Hymenoptera	2.7	0.2	<0.1	1.6	1.7	5.6	--	1.9	0.7	0.3	5.3	89.2	72.0	51.6	23.4	0.5
Hemiptera	--	--	3.8	0.3	9.0	--	3.6	--	1.6	6.8	13.7	17.8	29.3	25.9	0.7	0.9
Posocoptera	--	--	--	1.7	0.6	0.3	--	--	--	0.3	--	0.5	1.5	0.1	0.2	--
Isoptera	--	--	--	--	--	--	--	--	--	--	--	--	--	24.8	--	--
Microcoryphia	1.3	--	16.6	12.9	--	--	--	--	--	--	--	0.8	12.1	--	--	--
Chilopoda	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidoptera	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	13.8	--
Araneae	26.8	26.1	36.9	13.8	3.5	3.1	2.5	19.2	14.4	29.4	15.8	11.2	--	76.1	27.8	104.2
Oligochaeta	--	--	--	--	--	--	7.7	--	--	--	--	--	--	--	--	--
Total	188.1	961.5	481.3	999.5	174.4	101.1	105.7	84.3	118.9	192.1	224.1	668.1	402.8	324.7	320.3	129.5
Percent Aquatic	26	1.8	1.4	1.0	1.7	6.0	48.1	29.8	32.8	13.0	9.4	1.9	1.5	0.3	50.0	0.1

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a/ Includes adult Ephemeroptera, Plecoptera, and Trichoptera.

Appendix Table 11

Benthic macroinvertebrate mean density (no.m^{-2}) and 95 percent confidence limits, separated by size groups, for the treatment (Stations 85 and 850) and control (Station 1175) zones in Bear Creek, before (1978) and after (1979) streamside timber removal

Size Group (mm)	Pretreatment Period (1978)								Posttreatment Period (1979)							
	3-9	4-3	5-16	6-13	7-11	8-14	9-12	10-11	3-19	4[a]	5-4	6-6	7-2	8-1	9-4	10-3
Station 85 - Lower Treatment Zone																
0-3	2,625	2,770	3,512	4,210	15,590	18,830	6,042	10,932	2,150	--	3,292	12,800	10,500	9,420	7,715	9,007
3-6	887	1,635	1,762	1,972	2,237	2,302	727	1,350	302	--	1,272	1,750	823	2,930	2,620	2,615
6-9	77	110	200	205	260	262	152	215	52	--	135	160	100	200	265	395
9-12	15	37	18	23	33	43	29	15	3	--	8	10	0	20	0	120
>12	3	15	10	37	30	35	35	30	5	--	20	0	0	90	60	43
Combined	3,607	4,567	5,502	6,447	18,150	21,472	6,985	12,542	2,512	--	4,727	14,720	11,423	12,660	10,660	12,180
95 percent C.L. ±	2,165	4,386	3,546	3,485	7,130	20,830	3,231	2,516	1,821	--	3,380	11,722	8,203	8,545	2,567	10,561
N	4	4	4	4	4	4	4	4	4	--	4	4	3	4	4	4
Station 850 - Upper Treatment Zone																
0-3	2,363	3,830	2,745	3,260	11,510	15,775	7,260	6,742	5,377	--	7,043	9,640	31,700	21,760	17,540	41,050
3-6	160	1,152	1,187	1,110	1,476	1,125	740	702	892	--	2,406	3,350	3,070	2,373	1,140	1,670
6-9	23	70	107	80	260	175	86	57	50	--	303	450	450	213	60	210
9-12	10	32	15	0	13	20	20	8	3	--	11	0	60	27	20	20
>12	0	3	13	3	17	20	40	8	3	--	17	20	0	13	40	60
Combined	2,556	5,087	4,067	4,453	13,276	17,115	8,146	7,517	6,325	--	9,780	13,460	35,280	24,386	18,800	43,010
95 percent C.L. ±	595	5,067	2,265	5,407	8,224	2,483	5,536	3,089	1,667	--	8,535	4,093	31,051	31,712	16,021	36,017
N	3	4	4	3	3	4	3	4	4	--	3	4	4	3	4	4
Station 1175 - Control Zone																
0-3	2,851	2,075	2,922	6,080	18,772	17,935	12,333	12,076	5,513	--	4,180	16,440	25,985	23,170	30,020	45,000
3-6	327	622	1,574	1,335	1,762	1,217	520	380	643	--	1,020	3,020	2,875	1,380	1,940	1,240
6-9	65	25	176	135	195	168	120	36	50	--	140	320	375	200	260	200
9-12	18	5	9	5	25	47	26	23	4	--	10	30	22	10	0	80
>12	16	10	9	10	18	28	53	18	3	--	7	0	0	30	20	20
Combined	3,277	2,737	4,690	7,565	20,772	19,395	13,053	12,533	6,213	--	5,357	19,810	29,257	24,790	32,240	46,540
95 percent C.L. ±	21,026	2,219	4,319	21,773	8,777	7,350	11,261	11,948	2,837	--	6,034	18,837	11,929	15,520	18,811	45,115
N	2	4	2	2	4	4	3	3	3	--	4	4	4	4	4	4

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[a] Samples not collected during this period.

Appendix Table 12

Benthic macroinvertebrate mean biomass (gm^{-2}, wet weight) and 95 percent confidence limits, separated by size groups, for the treatment (Stations 85 and 850) and control (Station 1175) zones in Bear Creek, before (1978) and after (1979) streamside timber removal

Size Group (mm)	Pretreatment Period (1978)										Posttreatment Period (1979)					
	3-9	4-3	5-16	6-13	7-11	8-14	9-12	10-11	3-19	4[a]	5-4	6-6	7-2	8-1	9-4	10-3
Station 85 - Lower Treatment Zone																
0-3	0.24	0.23	0.27	0.22	0.99	1.90	0.61	0.85	0.18	--	0.27	0.47	0.45	0.28	0.32	0.17
3-6	0.56	1.32	1.70	1.03	1.59	2.01	0.98	1.17	0.42	--	1.54	1.14	0.75	0.97	1.54	0.79
6-9	0.61	0.55	1.37	0.93	0.81	1.14	0.43	0.37	0.29	--	0.87	0.49	0.71	0.40	0.62	0.83
9-12	0.12	0.46	0.38	0.23	0.61	0.60	0.21	0.44	0.04	--	0.05	0.19	--	0.01	--	0.47
>12	0.18	1.31	1.43	1.49	2.40	4.52	2.07	4.08	0.97	--	0.82	--	--	1.82	3.14	4.29
Combined	1.71	3.87	5.15	3.90	6.40	10.17	4.30	6.91	1.90	--	3.55	2.29	1.91	3.48	5.62	6.55
95 percent C.L. ±	1.10	3.96	4.87	2.65	2.04	12.80	2.63	11.34	2.94	--	3.14	2.53	2.44	3.68	2.54	11.23
N	4	4	4	4	4	4	4	4	4	--	4	4	4	4	4	4
Station 850 - Upper Treatment Zone																
0-3	0.28	0.29	0.15	0.20	0.65	1.05	0.53	0.74	0.45	--	0.59	0.38	0.96	1.18	1.08	1.17
3-6	0.19	1.35	1.14	0.66	1.05	0.65	0.70	0.80	0.73	--	2.68	3.41	1.98	1.81	1.32	1.09
6-9	0.13	0.49	0.67	0.30	0.80	0.36	0.32	0.12	0.29	--	1.35	1.27	1.10	0.49	0.43	0.66
9-12	0.11	0.57	0.19	--	0.25	0.21	0.56	0.10	0.03	--	0.08	--	0.39	0.03	0.28	0.32
>12	--	1.21	2.54	0.43	1.12	1.76	2.58	0.54	0.60	--	1.74	0.90	--	0.56	2.85	11.02
Combined	0.71	3.91	4.69	1.59	3.87	4.03	4.69	2.30	2.10	--	6.44	5.96	4.43	4.07	5.96	14.26
95 percent C.L. ±	0.59	5.24	3.88	1.03	6.34	2.79	9.25	2.74	1.61	--	3.72	3.91	3.15	7.35	7.28	25.56
N	3	4	4	3	3	4	3	4	4	--	3	4	4	3	4	4
Station 1175 - Control Zone																
0-3	0.21	0.18	0.37	0.25	0.76	0.77	0.76	0.85	0.33	--	0.09	0.51	0.59	0.75	0.70	0.65
3-6	0.14	0.43	2.38	0.79	1.57	0.92	0.51	0.44	0.44	--	0.65	1.36	1.31	0.94	1.46	0.74
6-9	0.14	0.09	0.97	0.35	0.74	0.52	0.25	0.14	0.49	--	0.36	0.76	0.49	0.40	0.88	0.22
9-12	0.57	0.09	0.27	0.06	0.31	0.94	0.39	0.62	0.02	--	0.07	0.28	0.04	0.26		0.64
>12	2.36	1.17	0.94	0.43	1.79	1.41	5.22	1.02	0.06	--	0.28			2.86	1.78	1.15
Combined	3.42	1.96	4.93	1.88	5.17	4.56	7.13	3.07	1.34	--	1.45	2.91	2.43	5.21	4.82	3.40
95 percent C.L. ±	39.76	4.03	14.02	13.70	3.50	1.77	16.82	3.82	1.49	--	0.61	2.74	0.73	6.50	6.06	3.00
N	2	4	2	2	4	4	3	3	3	--	4	4	4	4	4	4

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a/ Samples not collected during this period.

Appendix Table 13

Mean monthly water temperature (°C) for treatment (Stations 100 and 675) and control (Station 1175) zones of Bear Creek before (1977-78) and after (1979-80) streamside timber removal

Month	1977	1978	1979	1980
		Station 100		
January	--	6.1	2.3	3.4 [a]
February	5.3	6.2	4.4	5.6 [a]
March	4.1	6.5	5.9	6.6 [a]
April	6.2	6.7	7.0	8.9 [a]
May	8.2	8.1	9.4	8.3
June	10.8	10.5	11.4	11.2
July	11.5	12.8	13.0	12.1
August	13.4	12.9	14.1	12.6
September	11.3	11.0	11.8	11.4
October	8.3	10.0	10.7	--
November	6.5	5.8	6.2 [b]	--
December	5.9	4.2	5.0 [b]	--
		Station 675		
January	--	6.1 [b]	2.4 [c]	3.4 [c]
February	5.4 [b]	6.2 [b]	4.3 [c]	5.4 [c]
March	4.3 [b]	6.3 [b]	5.6 [c]	6.3 [c]
April	6.2 [b]	6.7 [b]	6.3	8.3 [c]
May	8.0 [b]	8.1 [b]	8.8	7.8 [c]
June	10.3 [b]	10.6 [b]	10.4	10.3 [c]
July	11.2 [b]	12.7 [b]	11.8	11.1 [c]
August	13.3 [b]	12.5 [b]	12.5	11.6 [c]
September	11.0 [b]	10.6 [b]	11.5	10.5 [c]
October	8.3 [b]	9.7 [b]	10.2	--
November	6.7 [b]	5.8 [b]	5.9 [c]	--
December	6.0 [b]	4.2 [b]	4.8 [c]	--

Appendix Table 13 (Continued)

Month	1977	1978	1979	1980
		Station 1125		
January	--	6.0	2.8 [f]	3.8 [f]
February	5.5 [d]	6.1	4.6 [f]	5.6 [f]
March	4.5 [d]	6.0	5.7	6.4 [f]
April	6.3 [d]	6.6	6.7	8.4 [f]
May	7.8	8.0	8.6	8.0
June	9.9	10.7	9.8	9.5
July	11.0	12.5	11.7	11.6
August	13.2	12.1	12.2	11.7
September	10.8	10.4	11.7	10.4 [f]
October	8.4	9.4	10.5	--
November	6.9	5.7 [e]	6.1 [f]	--
December	6.1	4.1 [e]	5.1 [f]	--

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[a] Based on a regression between Bear Creek and Peterson Creek: $y = -19.983a + 0.54x$, $r = 0.91$.

[b] Assumed temperature was the median of temperature at Stations 100 and 1125.

[c] Based on a regression between Station 675 and 100 (1979): $y = 0.413a + 0.886x$, $r = 0.99$.

[d] Based on a regression between Station 1125 and 100 (1977): $y = 0.814a + 0.890x$, $r = 0.99$.

[e] Based on a regression between Station 1125 and 100 (1978): $y = 0.169a + 0.948x$, $r = 0.99$.

[f] Based on a regression between Station 1125 and 100 (1979): $y = 0.940a + 0.883x$, $r = 0.98$.

Appendix Table 14

Mean monthly consumption rate (mg$g^{-1}d^{-1}$, wet wt.) for cutthroat trout in section 0-500 of Bear Creek during 1977-1980

Age Group	Month	1977	1978	1979	1980
0	Aug	136	118	146	104
	Sep	78	69	90	77
	Oct	35	50	60	--
	Nov	20	17	20	--
	Dec	19	13	13	--
I	Jan	--	20	7	9
	Feb	--	21	12	16
	Mar	--	33	21	24
	Apr	--	33	34	39
	May	--	35	46	33
	Jun	--	50	62	56
	Jul	--	76	70	61
	Aug	77	71	85	60
	Sep	45	41	48	41
	Oct	21	30	34	--
	Nov	13	10	12	--
	Dec	11	7	8	--
II	Jan	--	12	4	6
	Feb	--	13	7	10
	Mar	--	18	12	13
	Apr	--	20	21	24
	May	--	23	33	20
	Jun	--	31	36	32
	Jul	--	40	34	33
	Aug	36	34	39	34
	Sep	21	19	22	24
	Oct	10	14	16	--
	Nov	6	5	5	--
	Dec	6	3	4	--
III	Jan	--	6	2	3
	Feb	--	6	4	6
	Mar	--	9	6	10
	Apr	--	10	10	7
	May	--	9	15	6
	Jun	--	11	15	10
	Jul	--	22	11	12
	Aug	--	13	12	13
	Sep	--	--	6	9

Appendix Table 15

Mean monthly consumption rate ($mgg^{-1}d^{-1}$, wet wt.) for cutthroat trout in section 500-1000 of Bear Creek during 1977-1980

Age Group	Month	1977	1978	1979	1980
0	Aug	133	97	117	87
	Sep	65	61	83	63
	Oct	35	45	54	--
	Nov	22	16	19	--
	Dec	19	11	13	--
I	Jan	--	19	8	11
	Feb	--	21	12	16
	Mar	--	29	26	21
	Apr	--	36	32	39
	May	--	37	39	36
	Jun	--	49	48	50
	Jul	--	72	56	50
	Aug	80	64	60	51
	Sep	43	38	44	36
	Oct	22	29	31	--
	Nov	15	10	10	--
	Dec	13	7	8	--
II	Jan	--	13	5	6
	Feb	--	14	7	10
	Mar	--	16	12	14
	Apr	--	21	22	23
	May	--	27	27	19
	Jun	--	31	26	28
	Jul	--	35	25	30
	Aug	39	29	26	26
	Sep	20	17	21	19
	Oct	10	13	15	--
	Nov	7	5	5	--
	Dec	6	3	4	--
III	Jan	--	6	1	3
	Feb	--	6	3	6
	Mar	--	8	5	12
	Apr	--	9	10	10
	May	--	11	14	7
	Jun	--	16	15	8
	Jul	--	22	9	--
	Aug	--	18	9	--
	Sep	--	10	7	--

Appendix Table 16

Mean monthly consumption rate ($mgg^{-1}d^{-1}$, wet wt.) for cutthroat trout in section 1000-1200 of Bear Creek during 1977-1980

Age Group	Month	1977	1978	1979	1980
0	Aug	132	97	114	84
	Sep	67	59	91	58
	Oct	34	42	61	--
	Nov	24	17	20	--
	Dec	20	10	15	--
I	Jan	--	21	9	11
	Feb	--	24	14	17
	Mar	--	24	20	24
	Apr	--	34	27	40
	May	--	35	43	34
	Jun	--	52	43	41
	Jul	--	72	54	60
	Aug	75	62	57	55
	Sep	40	39	50	37
	Oct	22	29	37	--
	Nov	15	11	13	--
	Dec	12	8	10	--
II	Jan	--	12	6	7
	Feb	--	13	9	11
	Mar	--	15	13	15
	Apr	--	19	23	24
	May	--	25	29	21
	Jun	--	33	28	24
	Jul	--	33	29	32
	Aug	35	26	26	29
	Sep	20	17	21	18
	Oct	11	13	16	--
	Nov	8	5	5	--
	Dec	7	4	4	--
III	Jan	--	7	3	3
	Feb	--	7	4	5
	Mar	--	11	7	6
	Apr	--	15	11	11
	May	--	8	12	9
	Jun	--	11	14	12
	Jul	--	15	10	--
	Aug	--	13	8	--
	Sep	--	8	6	--

Appendix Table 17

Cutthroat trout population estimates and 95 percent confidence interval for Section 0 to 500 of Bear Creek

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
07/20/77	3[a]	2	1	0			
	3	21	226	110			
	--[b]	12-51	179-273	86-134			
09/07/77	3	2	1	0			
	4	11	215	136			
	2-8	5-27	172-259	92-225			
04/24/78		3	2	1			
		23	65	77			
		9-46	40-125	49-143			
07/17/78		3	2	1	0		
		7	45	160	382		
		4-18	22-109	133-187	336-427		
10/03/78		3	2	1	0		
		5	17	125	233		
		2-11	10-39	91-188	192-275		
04/01/79			3	2	1		
			20	92	148		
			15-44	52-193	113-182		
05/12/79			3	2	1		
			5	25	248		
			---	16-50	170-392		
07/18/79			3	2	1	0	
			3	51	152	54	
			2-8	26-120	128-177	25-133	
08/29/79			3	2	1	0	
			3	30	164	59	
			3-7	22-50	126-201	44-91	
10/15/79			3	2	1	0	
			7	27	137	63	
			4-14	23-39	123-151	46-97	

Appendix Table 17 (Continued)

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
04/07/80				3	2	1	
				13	63	53	
				5-26	39-120	25-130	
07/15/80				3	2	1	0
				5	19	97	841
				2-11	12-41	48-236	645-1137
09/25/80				3	2	1	0
				4	43	58	775
				2-8	26-89	40-105	650-900

---

a/ Age group.

b/ Minimum estimate, confidence interval cannot be computed.

Appendix Table 18

Cutthroat trout population estimates and 95 percent confidence interval for Section 500 to 1000 of Bear Creek

Sample Date	Year Class 1974	1975	1976	1977	1978	1979	1980
07/20/77	3[a]	2	1	0			
	3	15	198	112			
	--[b]	9-35	169-227	74-189			
09/07/77	3	2	1	0			
	1	19	221	95			
	1-3	12-39	166-276	73-117			
04/24/78		3	2	1			
		6	82	73			
		3-15	37-200	48-133			
07/17/78		3	2	1	0		
		2	16	142	394		
		---	10-32	127-158	343-445		
10/03/78		3	2	1	0		
		7	13	137	258		
		4-14	8-31	113-162	203-312		
04/01/79			3	2	1		
			18	95	147		
			12-41	62-169	119-176		
05/12/79			3	2	1		
			10	68	221		
			---	41-136	178-264		
07/18/79			3	2	1	0	
			5	45	236	189	
			---	31-76	184-289	124-325	
08/29/79			3	2	1	0	
			2	24	178	162	
			2-5	17-43	148-208	133-192	
10/15/79			3	2	1	0	
			6	45	176	149	
			---	34-68	157-196	136-163	

Appendix Table 18 (Continued)

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
				3	2	1	
04/07/80				8	61	104	
				---	42-106	66-192	
				3	2	1	0
07/15/80				6	27	83	359
				4-15	18-52	64-120	279-440
				3	2	1	0
09/25/80				0	32	107	469
				---	21-63	70-186	376-561

---

a/ Age group.

b/ Minimum estimate, confidence interval cannot be computed.

Appendix Table 19

Cutthroat trout population estimates and 95 percent confidence interval for Section 1000 to 1200 of Bear Creek

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
07/20/77	3[a]	2	1	0			
	0	8	118	116			
	--[b]	7-15	92-194	95-167			
09/07/77	3	2	1	0			
	0	8	60	114			
	---	8-13	56-71	87-190			
04/24/78		3	2	1			
		5	19	70			
		---	7-38	40-148			
07/17/78		3	2	1	0		
		3	12	89	139		
		---	7-26	79-99	110-168		
10/03/78		3	2	1	0		
		1	5	66	94		
		---	---	54-86	64-156		
04/01/79			3	2	1		
			4	54	82		
			2-11	33-107	51-153		
05/12/79			3	2	1		
			2	19	88		
			2-5	11-44	62-137		
07/18/79			3	2	1	0	
			0	11	101	118	
			---	9-24	67-175	49-285	
08/29/79			3	2	1	0	
			1	7	62	76	
			---	3-15	43-101	54-121	
10/15/79			3	2	1	0	
			1	6	49	81	
			---	---	41-63	66-96	

Appendix Table 19 (Continued)

Sample Date	Year Class 1974	1975	1976	1977	1978	1979	1980
04/07/80				3	2	1	
				1	35	48	
				---	17-85	24-117	
07/15/80				3	2	1	0
				1	9	29	109
				---	5-23	12-71	70-190
09/25/80				3	2	1	0
				0	12	33	179
				---	7-30	18-76	111-326

---

a/ Age group.
b/ Minimum estimate, confidence interval cannot be computed.

Appendix Table 20

Cutthroat trout mean weight (g, wet wt.) and 95 percent confidence interval for Section 0 to 500 of Bear Creek

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
	3[a]	2	1	0			
07/20/77	32.70	22.59	9.38	1.08			
	25.20-	19.37-	8.95-	0.96-			
	40.20	25.81	9.82	1.20			
	3	2	1	0			
09/07/77	41.30	23.34	10.21	2.28			
	20.07-	20.64-	9.74-	2.10-			
	62.53	26.03	10.68	2.46			
		3	2	1			
04/24/78		31.13	13.00	5.15			
		25.35-	11.89-	4.57-			
		36.90	14.10	5.73			
		3	2	1	0		
07/17/78		38.91	20.97	8.80	1.71		
		32.84-	19.41-	8.19-	1.63-		
		44.97	22.52	9.42	1.79		
		3	2	1	0		
10/03/78		43.32	24.94	11.61	3.34		
		39.73-	22.97-	10.72-	3.18-		
		46.92	26.91	12.50	3.49		
			3	2	1		
04/01/79			26.38	11.14	3.84		
			22.23-	10.14-	3.58-		
			30.54	12.15	4.10		
			3	2	1		
05/12/79			33.20	15.29	6.23		
			22.58-	13.66-	5.83-		
			43.82	16.92	6.63		
			3	2	1	0	
07/18/79			44.94	24.13	10.45	1.15	
			33.65-	21.90-	9.82-	0.92-	
			56.24	26.35	11.07	1.39	

Appendix Table 20 (Continued)

Sample Date	Year Class 1974	1975	1976	1977	1978	1979	1980
			3	2	1	0	
08/29/79			42.09	25.14	11.32	2.59	
			30.43-	23.31-	10.68-	2.34-	
			53.74	26.97	11.96	2.84	
			3	2	1	0	
10/15/79			40.24	26.82	12.70	3.98	
			36.06-	25.07-	12.13-	3.72-	
			44.42	28.57	13.28	4.23	
				3	2	1	
04/07/80				34.60	13.95	5.39	
				28.37-	12.55-	4.92-	
				40.83	15.35	5.85	
				3	2	1	0
07/15/80				38.30	20.03	10.54	1.75
				26.19-	17.81-	9.92-	1.66-
				50.41	22.24	11.15	1.84
				3	2	1	0
09/25/80				45.97	23.43	13.27	3.62
				36.59-	21.44-	12.49-	3.48-
				55.35	25.42	14.06	3.75

---

a/ Age group.

Appendix Table 21

Cutthroat trout mean weight (g, wet wt.) and 95 percent confidence interval for Section 500 to 1000 of Bear Creek

Sample Date	Year Class 1974	1975	1976	1977	1978	1979	1980
07/20/77	3[a] 44.20 ---[b]	2 20.78 19.05- 22.52	1 8.36 7.87- 8.84	0 1.17 1.04- 1.29			
09/07/77	3 37.00 ---[b]	2 22.39 20.43- 24.35	1 9.32 8.81- 9.82	0 2.56 2.39- 2.73			
04/24/78		3 25.00 21.54- 28.46	2 12.68 11.64- 13.72	1 4.99 4.35- 5.63			
07/17/78		3 31.71 30.37- 33.04	2 22.64 19.79- 25.49	1 9.05 8.44- 9.66	0 1.78 1.69- 1.87		
10/03/78		3 39.24 33.94- 44.54	2 25.24 22.86- 27.62	1 11.11 10.38- 11.85	0 3.17 3.01- 3.33		
04/01/79			3 24.70 21.22- 28.18	2 10.99 10.05- 11.93	1 3.94 3.68- 4.20		
05/12/79			3 29.88 27.15- 32.60	2 16.65 15.30- 18.00	1 6.40 6.03- 6.76		
07/18/79			3 41.59 37.81- 45.38	2 23.65 21.96- 25.34	1 9.97 9.45- 10.48	0 0.75 0.70- 0.80	

Appendix Table 21 (Continued)

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
			3	2	1	0	
08/29/79			42.51	23.97	11.22	2.21	
			41.37-	21.59-	10.63-	2.07-	
			43.65	26.34	11.80	2.35	
			3	2	1	0	
10/15/79			42.00	24.36	11.38	3.34	
			37.18-	22.87-	10.88-	3.16-	
			46.82	25.85	11.88	3.52	
				3	2	1	
04/07/80				33.55	12.76	4.07	
				28.53-	11.69-	3.72-	
				38.56	13.83	4.43	
				3	2	1	0
07/15/80				46.06	18.32	9.65	1.67
				30.27-	16.71-	9.15-	1.56-
				61.85	19.94	10.14	1.77
				3	2	1	0
09/25/80				---[c]	21.59	12.49	3.74
					19.38-	11.88-	3.58-
					23.80	13.10	3.90

---

a/ age group
b/ n = 1, no variance.
c/ no estimate.

Appendix Table 22

Cutthroat trout mean weight (g, wet wt.) and 95 percent confidence interval for Section 1000 to 1200 of Bear Creek

Sample Date	Year Class						
	1974	1975	1976	1977	1978	1979	1980
07/20/77	3[a] ---[c]	2 21.65 15.14- 28.16	1 9.14 7.98- 10.31	0 0.97 0.81- 1.13			
09/07/77	3 ---[c]	2 21.27 18.85- 23.70	1 9.95 8.76- 11.14	0 2.33 2.10- 2.55			
04/24/78		3 30.44 19.76- 41.12	2 12.53 11.07- 13.99	1 4.92 4.36- 5.47			
07/17/78		3 39.66 14.91- 64.40	2 22.49 19.63- 25.35	1 8.10 7.43- 8.77	0 1.89 1.72- 2.06		
10/03/78		3 32.27 ---[b]	2 23.28 19.57- 26.98	1 9.48 8.71- 10.26	0 3.42 3.17- 3.68		
04/01/79			3 25.28 15.59- 34.36	2 10.17 9.08- 11.26	1 4.12 3.75- 4.48		
05/12/79			3 30.78 4.67- 56.90	2 14.48 12.39- 16.57	1 5.92 5.36- 6.47		
07/18/79			3 ---[c]	2 22.86 20.56- 25.17	1 9.51 8.57- 10.44	0 0.78 0.70- 0.85	

Appendix Table 22 (Continued)

Sample Date	Year Class 1974	1975	1976	1977	1978	1979	1980
08/29/79			3 44.71 ---b/	2 25.15 17.80- 32.51	1 9.85 8.94- 10.75	0 1.86 1.76- 1.96	
10/15/79			3 44.58 ---b/	2 24.40 20.83- 27.97	1 10.63 9.71- 11.54	0 3.11 2.92- 3.29	
04/07/80				3 25.12 ---b/	2 12.72 10.87- 14.57	1 4.02 3.43- 4.62	
07/15/80				3 29.40 ---b/	2 19.76 14.92- 24.61	1 8.29 7.43- 9.15	0 2.17 1.96- 2.38
09/25/80				3 ---c/	2 24.06 19.98- 28.13	1 10.77 9.72- 11.82	0 3.90 3.56- 4.24

---

a/ age group
b/ n = 1, no variance.
c/ no estimate.

Appendix Table 23

Relative daily growth rate (mgg^{-1}d^{-1}, wet wt.) by month for cutthroat trout in section 0-500 of Bear Creek during 1977-1980. Estimates based on mean weights derived from Figure 24.

Age Group	Month	1977	1978	1979	1980
0	Aug	14.4	13.5	7.4	9.2
	Sep	7.4	5.7	13.1	8.1
	Oct	1.3	2.0	5.0	
	Nov	-1.3	0	1.5	
	Dec	0	1.0	0	
I	Jan		0	0	0
	Feb		1.3	0	0.7
	Mar		11.7	3.6	4.1
	Apr		12.0	11.5	6.4
	May		7.8	9.9	6.7
	Jun		6.3	9.4	7.0
	Jul		5.3	2.9	5.5
	Aug	1.7	4.3	2.1	3.7
	Sep	1.3	2.1	2.5	2.3
	Oct	0	0	1.1	
	Nov	-0.3	-0.3	0.8	
	Dec	-0.3	-0.3	0	
II	Jan		-0.3	-0.3	0
	Feb		0	-0.6	0.2
	Mar		3.7	0.6	1.5
	Apr		6.2	6.2	3.9
	May		6.2	10.0	4.1
	Jun		6.1	7.5	3.8
	Jul		4.4	2.1	2.3
	Aug	1.0	2.4	1.3	1.9
	Sep	0.6	1.1	1.3	2.0
	Oct	0.4	0.5	0.9	
	Nov	0	-0.1	0.5	
	Dec	0.1	-0.3	0.1	
III	Jan		0.3	0.3	0.2
	Feb		0.7	0.3	1.9
	Mar		3.3	1.2	5.0
	Apr		4.6	4.6	1.3
	May		3.2	6.2	0.9
	Jun		2.5	5.2	1.3
	Jul		3.2	0.6	1.6
	Aug		1.6	-0.5	2.6
	Sep			-1.3	2.4

Appendix Table 24

Relative daily growth rate ($mgg^{-1}d^{-1}$, wet wt.) by month for cutthroat trout in section 500-1000 of Bear Creek during 1977-1980. Estimates based on mean weights derived from Figure 25.

Age Group	Month	1977	1978	1979	1980
0	Aug	15.7	5.1	19.0	11.9
	Sep	1.4	4.5	10.0	7.9
	Oct	1.3	0	3.1	
	Nov	0	-1.1	1.0	
	Dec	0	-1.1	0	
I	Jan		0	0	0.9
	Feb		1.3	0	0.9
	Mar		8.7	8.7	1.8
	Apr		14.5	13.2	8.3
	May		10.1	8.6	10.3
	Jun		5.1	7.2	8.6
	Jul		4.1	4.0	5.2
	Aug	2.6	3.3	2.4	4.0
	Sep	0.4	1.8	0.6	2.8
	Oct	0.4	0.6	0.3	
	Nov	0	-0.6	-0.3	
	Dec	0	-0.9	0	
II	Jan		0	-0.3	0
	Feb		0.3	-0.6	0.3
	Mar		2.6	1.2	2.2
	Apr		7.1	10.0	4.0
	May		9.5	9.1	3.8
	Jun		6.9	5.7	3.6
	Jul		3.0	1.4	3.3
	Aug	1.8	1.8	0.3	2.3
	Sep	0.4	1.1	0.3	1.7
	Oct	0.1	0.4	0.3	
	Nov	-0.1	0	0.1	
	Dec	0	-0.1	0.1	
III	Jan		0	-0.8	0.3
	Feb		0.1	-0.5	2.0
	Mar		1.4	0.1	7.0
	Apr		2.6	4.5	4.5
	May		2.7	5.8	3.3
	Jun		2.8	6.2	2.6
	Jul		3.3	1.1	
	Aug		3.3	0.4	
	Sep		1.9	-0.4	

Appendix Table 25

Relative daily growth rate (mgg^{-1}d^{-1}, wet wt.) by month for cutthroat trout in section 1000-1200 of Bear Creek during 1977-1980. Estimates based on mean weights derived from Figure 26.

Age Group	Month	1977	1978	1979	1980
0	Aug	16.0	10.3	21.4	9.3
	Sep	4.5	5.1	12.9	5.6
	Oct	0	0.9	5.5	
	Nov	0	0	1.0	
	Dec	0	-0.9	0	
I	Jan		1.3	0.9	0
	Feb		4.9	0.9	1.0
	Mar		5.3	3.4	4.5
	Apr		13.5	6.6	8.7
	May		8.1	12.6	7.4
	Jun		4.8	7.0	5.6
	Jul		3.4	2.1	5.6
	Aug	2.1	2.7	1.0	3.8
	Sep	0.7	1.8	1.3	1.9
	Oct	0.3	0.7	1.6	
	Nov	0	0	0.6	
	Dec	-0.3	0	0.3	
II	Jan		-0.3	0	0.6
	Feb		0.6	0.3	0.6
	Mar		2.8	1.0	2.2
	Apr		5.5	8.1	4.3
	May		8.7	9.2	5.1
	Jun		7.5	7.4	4.6
	Jul		2.1	3.7	3.9
	Aug	-0.6	0.6	1.1	3.2
	Sep	-0.2	0.4	0.1	1.3
	Oct	-0.2	0.1	0	
	Nov	-0.2	0	-0.1	
	Dec	-0.2	0	-0.1	
III	Jan		0.2	0	0
	Feb		0.5	0.1	0.1
	Mar		4.5	2.2	0.5
	Apr		8.6	5.0	1.4
	May		1.9	5.2	1.6
	Jun		1.0	6.5	1.4
	Jul		0.9	2.2	
	Aug		0.5	0.3	
	Sep		0.4	-0.1	

Appendix Table 26

Monthly production (g, wet wt.) of cutthroat trout in Section 0-500 of Bear Creek during 1977-1980. Numbers in parenthesis are production (gm^{-2}, wet wt.)

Age Group	Month	Year			
		1977	1978	1979	1980
0	August	86	282	37	571
	September	56	132	81	631
	October	10	46	37	
	November	-10	0	11	
	December	0	19	0	
		142	479	166	1,202
		(.104)	(.352)	(.122)	(.883)
I	January		0	0	0
	February		8	0	5
	March		84	61	30
	April		124	328	76
	May		185	453	143
	June		239	483	197
	July		224	150	163
	August	109	190	108	108
	September	81	94	130	64
	October	0	0	54	
	November	-16	-12	36	
	December	-14	-11	0	
		160	1,125	1,803	786
		(.117)	(.826)	(1.324)	(.577)
II	January		-12	-11	0
	February		0	-20	8
	March		108	18	44
	April		173	153	113
	May		174	212	113
	June		174	182	95
	July		127	54	54
	August	17	67	32	43
	September	9	28	29	46
	October	6	12	18	
	November	0	-3	9	
	December	2	-5	2	
		34	843	678	516
		(.025)	(.619)	(.498)	(.379)

Appendix Table 26 (Continued)

Age Group	Month	Year 1977	 1978	 1979	 1980
III	January		4	5	4
	February		9	5	25
	March		47	19	66
	April		69	56	17
	May		44	55	10
	June		28	46	11
	July		20	5	11
	August		15	-4	14
	September		9	-8	11
			245 (.180)	179 (.131)	169 (.124)
All	TOTAL	336 (.246)	2,692 (1.977)	2,826 (2.075)	2,673 (1.963)

Appendix Table 27

Monthly production (g, wet wt.) of cutthroat trout in Section 500-1000 of Bear Creek during 1977-1980. Numbers in parenthesis are production (gm^{-2}, wet wt.)

Age Group	Month	Year 1977	1978	1979	1980
0	August	94	136	174	372
	September	9	114	126	363
	October	8	0	44	
	November	0	-21	14	
	December	0	-19	0	
		111	210	358	735
		(.090)	(.169)	(.289)	(.593)
I	January		0	0	12
	February		7	0	11
	March		56	132	21
	April		147	358	111
	May		227	380	175
	June		175	420	187
	July		157	277	136
	August	142	140	163	116
	September	19	82	36	89
	October	18	27	17	
	November	0	-25	-15	
	December	0	-36	0	
		179	957	1,768	858
		(.144)	(.772)	(1.426)	(.692)
II	January		0	-11	0
	February		10	-21	9
	March		76	39	60
	April		213	300	97
	May		265	300	84
	June		151	197	72
	July		54	46	61
	August	30	31	8	43
	September	6	18	8	31
	October	2	6	8	
	November	-2	0	3	
	December	0	-2	2	
		36	822	879	457
		(.029)	(.663)	(.709)	(.369)

Appendix Table 27 (Continued)

Age Group	Month	Year			
		1977	1978	1979	1980
III	January		0	-11	4
	February		1	-7	20
	March		11	2	62
	April		19	50	37
	May		17	53	25
	June		13	48	18
	July		16	8	
	August		17	2	
	September		10	-2	
			104 (.084)	143 (.115)	166 (.134)
All	TOTAL	326 (.263)	2,093 (1.688)	3,148 (2.539)	2,216 (1.788)

Appendix Table 28

Monthly production (g, wet wt.) of cutthroat trout in Section 1000-1200 of Bear Creek during 1977-1980. Numbers in parenthesis are production (gm^{-2}, wet wt.)

Age Group	Month	Year			
		1977	1978	1979	1980
0	August	94	99	93	113
	September	34	53	78	101
	October	0	9	37	
	November	0	0	7	
	December	0	-8	0	
		128	153	215	214
		(.201)	(.240)	(.337)	(.335)
I	January		8	8	0
	February		30	8	6
	March		36	32	26
	April		124	76	54
	May		124	211	48
	June		98	164	38
	July		71	58	41
	August	50	55	23	31
	September	12	35	23	17
	October	5	13	25	
	November	0	0	9	
	December	-4	0	4	
		63	594	641	261
		(.099)	(.931)	(1.005)	(.409)
II	January		-3	0	8
	February		6	6	8
	March		22	14	30
	April		40	114	55
	May		66	91	56
	June		62	58	42
	July		17	26	30
	August	-1	4	6	22
	September	-1	2	1	9
	October	-1	1	0	
	November	-1	0	-1	
	December	-1	0	-1	
		-5	217	314	260
		(-.008)	(.340)	(.492)	(.408)

Appendix Table 28 (Continued)

Age Group	Month	Year			
		1977	1978	1979	1980
III	January		1	0	0
	February		2	1	1
	March		19	7	1
	April		39	14	2
	May		10	12	1
	June		5	11	1
	July		3	3	
	August		1	0	
	September		1	0	
			81 (.127)	48 (.075)	6 (.009)
All	TOTAL	186 (.292)	1,045 (1.638)	1,218 (1.909)	741 (1.161)

VITA

Douglas John Martin was born November 9, 1948 in Green Bay, Wisconsin to Kenneth and Lorraine Martin. He graduated from Premontre High School in June 1967. He attended the University of Wisconsin, Stevens Point, and received a Bachelor of Science degree in Water Resource Management from the College of Natural Resources in June 1971. In January 1973 he entered the University of Washington, College of Fisheries and was awarded a Research Assistantship to study the effects of sedimentation from logging on the production of benthic macroinvertebrates in the Clearwater River, Washington. While a pre-master student, he received the Olympia Salmon Club Scholarship and the Wilber McLeod Chapman Memorial Scholarship. He received a Master of Science degree in March 1976. In autumn 1976 he became a fisheries biologist for the Fisheries Research Institute and was the project leader and/or co-principal investigator of several major studies. While working for FRI, he continued his education in the doctoral program at the College of Fisheries. In August 1983 he was hired by Envirosphere Company of Bellevue, Washington, where he continues to be employed as a Senior Associate Scientist.

In 1970, he married Judith Marian Merline and they have had five children: Jason Douglas, Tyler William, Lucas John, Noah James, and Eli Joseph. They currently reside in Seattle, Washington.